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Effects of Prescribed Burning on the Understory Vegetation in Pine-Hardwood Forests of Southeastern Louisiana.

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EFFECTS OF PRESCRIBED BURNING ON THE UNDERSTORY VEGETATION IN PINE-HARDWOOD FORESTS OF SOUTHEASTERN LOUISIANA

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ABSTRACT

Effects of prescribed burning on understory vegetation were studied in natural loblolly pine stands burned annually or periodically. Unburned stands were used for comparison. The study was conducted in the flatwoods and loessal hills of southeastern Louisiana. Stands were grouped into 25-35 year and 40-50 year age classes. Soils were grouped into three drainage classes. Stem totals were tabulated by burning treatment, soil drainage, and light as influenced by overstory density.

Cultural information and descriptive stand data were obtained. The data were analyzed statistically by analysis of variance, correlation analysis, and chi-square analysis.

In stands burned annually one-year-old pine seedlings constituted the largest number of stems in the understory. A small number of shrub and tree species comprised much of the understory; however, a large number of herbaceous species were common. Most of the understory was less than 3 feet in height.

Stands burned periodically showed more variation in species and stem totals than stands burned annually. A large number of common shrub and tree species and slightly more vine and herbaceous species were found in stands burned periodically. A larger percentage of the understory exceeded 3 feet in height compared with stands burned annually.

Unburned stands had a multistory effect which was lacking in stands that were prescribed burned. Each unburned stand was characterized by a large number of shrub and tree species, but herbaceous vegetation was limited.

Differences in stem totals between stands burned annually and periodically were quite large. Stands burned periodically had almost twice the number of hardwood stems compared with stands burned annually.

Differences in soil drainage were apparently responsible for large variation in stem totals. Better-drained soils had nearly twice the number of hardwood stems as poorer-drained soils.

Light appeared to be more important than burning treatment or soil drainage as an influence on stem totals. A 10 percent decrease in the overstory cover more than doubled the numbers of hardwood and total stems in the understory.

The most intensively burned stand (burned annually for 10 years) was characterized by serious or potentially serious fire damage to 25 percent of the pine tree boles.

Study of stand data and observation in the field led to the conclusion that several factors, such as soil drainage, stand age, overstory cover, height of canopy, amount of organic litter on the forest floor, and burning treatment, influenced understory development. Statistical analyses were used to isolate plant species as indicators of burning levels.

Five species, southern bayberry, American beautyberry, sumac, yaupon, and Vaccinium sp., were selected as potential indicators of various stages of understory control.

Analyses of of vine and herbaceous vegetation revealed high frequencies of occurrence on burned stands and low frequencies of occurrence on unburned stands. Legumes occurred frequently on burned sites, especially on better-drained soils.

The following conclusions are drawn from field data and observations:

Late winter or early spring prescribed burning kills as well as kills back hardwood understory.

A periodic burning program of 2- or 3-year intervals appears best for grazing improvement.

A periodic burning interval of 3 to 4 years is most satisfactory where multiple uses are required of the forested area.

If wildfires are not a problem, hardwood understory can be controlled on an 8- to 10-year burning interval.

Where hunters, cattlemen, and arsonists are all active, "protective" burning on a short interval or annual basis may be necessary.

Several unanswered questions on light-edaphic relations under various burning regimes need further study.

INTRODUCTION

Southern forestry essentially is oriented toward pine silviculture, and regular use of fire on a prescribed basis is now generally accepted throughout the South by most foresters and ecologists. Fire has been characteristic of the earth landscape for millions of years, long before man came on the scene. As a tool in shaping the pattern of vegetation, fire probably is unexcelled (Weaver 1951 and 1955, Cooper 1961, Eyre 1968). It is doubtful if any forested area on the earth surface has not been altered to some extent by fires caused by lightning, man, or possibly other natural causes (Phillips 1965, Komarek 1962 and 1964).

Sauer (1952) noted that man's greatest power to disturb the balance of nature lay in his employment of fire. Hunters, collectors, tillers, and pastoral people all used fire for some particular purpose. Stewart (1963) observed that the impact of vegetational changes as a result of fire used by aborigines has not been fully appreciated. It is known that aborigines used fire for various purposes over much of North America (Sauer 1952). It might even be said that Indians used "controlled" burning in the southern pine belt long before the European came upon the scene.

Some of the more primitive people, especially in tropical areas, still use fire in "shifting agriculture" and to improve grazing in the same manner as people did centuries ago (Stamp 1964, Phillips 1965). The tough savanna grasses are removed by fire so that new succulent growth can appear. In areas of tropical rainforest the slash-and-burn technique is used, particularly where subsistence agriculture is common.

Ecologists and foresters now agree that the most important timber species, pine particularly, owe their existence in one way or another to fire. Diligent research and observation by forest-oriented people have shown that the intolerant pine species cannot compete with the more tolerant hardwoods for very long. Careful use of fire at the proper time and under the right conditions can give pine the edge over hardwoods needed for growth to the desired harvest age. In some respects a climax forest of hardwoods may be desirable, but to the manager of pure pine forests extreme competition that results in the dominance of hardwoods ultimately eliminates the less tolerant pine.

Prescribed burning is defined as the skillful application of fire to natural fuels under conditions of weather, fuel moisture, and soil moisture that will allow confinement of the fire to a predetermined area and at the same time will produce the intensity of heat and rate of spread required to accomplish certain planned benefits to one or more objectives of silviculture, wildlife management, grazing, and hazard reduction. Its objective is to employ fire scientifically to realize maximum net benefits at minimum damage and acceptable costs (Society of American Foresters 1958). Usually when one objective of prescribed burning is obtained, concomitant benefits result from the operation.

The primary purpose of forest land management in Louisiana is the production and harvesting of forest products whether it be saw-timber, poles and piling, veneer bolts, or pulpwood. Fire is an important instrument in accomplishing the primary objective of growing timber. It is useful in other activities such as grazing and wildlife management.

Our present knowledge of the associations in understory vegetation is far from complete where forest land management is concerned. Weaver (1959) stressed that foresters should take more interest in ground cover since its treatment influences the success of silvicultural practices. A comprehensive review of the literature led Ahlgren and Ahlgren (1960) to conclude that each combination of region, climate, forest tree association, soil type, and plant species must be considered individually. We especially need to know more about the effects caused by prescribed burning at different time intervals and for varying numbers of burns on different soil types. Description and analyses of the understory under different burning regimes will add to our knowledge of forest management and ecology.

This research endeavor was designed to study the composition and structure of the understory vegetation, including tree reproduction, shrubs, vines, and herbs, under various prescribed-burning regimes. A selected number of understory woody species were chosen for study to determine if such indicator plants could be isolated to show burning regimes or at least control of undesirable hardwoods. In addition, the differences in the understory, if any, due to soil type, timber age, and stand treatment were sought. Since overstory cover and height of the overstory influences the amount of light reaching the forest floor, a correlation of the overstory cover with the understory development was also considered an objective for the study. It was anticipated that fairly complete stand description would be needed for the analysis.

Past research projects which attempted analysis of the understory vegetation in prescribed-burned areas were limited to the Coastal Plains and Piedmont regions of the southern states. In many research efforts the herbaceous vegetation was not considered.

The present study was established in the flatwoods and loessal hills areas of Livingston, St. Helena, and Tangipahoa Parishes of southeastern Louisiana. This important timber-growing region has been largely bypassed in previous studies. Furthermore, this area burns frequently due to wildfires and prescribed burning. The availability of burning records was of utmost importance to this study. The present study includes a broader combination of prescribed burning regimes than has been attempted before.

The results may be applied in various ways depending upon the forest land manager's objective. An acceptable burning interval for the control of undesirable understory species might not be appropriate for use in grazing areas. Burning for wildlife management is not most effective on an annual basis, since many shrubs require more than one season of growth for fruiting to occur. Accordingly, in the study location where grazing is common-place and hunters abound, forest management must contend with hardwood brush, hunters, and cattle in the process of growing timber. An acceptable compromise in burning interval is a desirable goal, but one which may be impossible to achieve. The variety of burning situations on different soil types and in different aged timber stands should provide practical information for management purposes.

REVIEW OF LITERATURE

There is no dearth of literature on prescribed burning. Although the literature was thoroughly reviewed, only the materials more pertinent to the present study are presented. In addition it was felt that a brief history of prescribed burning was desirable to illustrate the problems related to the use of this silvicultural concept in the South.

It is extremely difficult to isolate the effects of prescribed burning to one objective. Accordingly, many of the reviewed studies touch upon more than one objective of prescribed burning. It seems reasonable, therefore, to group the literature under the following headings: brief history of prescribed burning, control of understory hardwoods, hazard reduction, seedbed preparation for regeneration, improvement of wildlife habitat, improvement of grazing and understory species as plant indicators. The last heading does not involve prescribed burning but shows that the idea of using understory species as indicators for one reason or another is not new. As mentioned in the objectives of this study, it was anticipated that certain plants might serve as indicators of burning levels of understory control.

Brief History of Prescribed Burning

Our forest experience through World War II was one of conservation and suppression of any fire in the forests. In many cases this lesson was taught so well that people had to be "unlearned" in order to accept prescribed burning as a beneficial practice in its proper place.

Ecologists, as early as the 1880's, recognized the successional pattern in the South and suggested pine was the result of fire. In 1889, Mrs. Ellen Call Long of Tallahassee, Florida, spoke to a group attending a meeting of the American Forestry Congress and hypothesized that the vegetation on the hammocks of Florida was due to protection from fire (Harper 1962). One of the few farsighted foresters of the early part of this century who realized the results of fire was H. H. Chapman. He repeatedly called attention to the need for burning and pointed out observations that substantiated the early views of ecologists who maintained that fires at about 10-year intervals and hurricanes opened up areas for pine regeneration. Chapman suggested that loblolly pine (<u>Pinus taeda</u> L.) could be driven out of this type of natural balance by man's interference such as the excessive removal of seed sources, too frequent fires, and total exclusion of fire. The elimination of fire would permit hardwoods to become established before and following cutting so that pine seedlings that might be established would be overtopped and killed in an average of 5 years (Chapman and Hall 1947).

Some of the earlier research in the South dates to 1924. The primary purposes for burning in South Carolina loblolly pine stands appeared to be: (1) hazard reduction in young stands to minimize the danger from wildfire, (2) control of undesirable hardwoods and shrubs in immature stands so as to facilitate later establishment of pine seedlings, and (3) removal of heavy litter and residual plant competitors which might interfere with natural reseeding at harvest time in mature stands (Lotti 1962). These same objectives are desirable today.

Burns (1952) described exploratory burns for seedbed preparation in oak-shortleaf pine (Pinus echinata Mill.) and pitch pine (Pinus rigida Mill.) stands in New Jersey during the 1930's. Later in the 1940's, the use of controlled burns in longleaf (Pinue palustris Mill.) and slash pine (Pinus elliottii Engelm.) for hazard reduction was reluctantly accepted. The breakthrough led to the use of fire as a silvicultural tool for seedbed preparation and control of brownspot disease (Scirrhia acicola) in longleaf pine.

In 1947 Chapman proposed prescribed burning of loblolly pine stands for seedbed preparation and understory hardwood control. His proposal was not readily accepted for the following reasons (Silker 1957): (1) failure to recognize the ecological position of southern pine as a fire climax group; (2) lack of resource data showing the scope of hardwood encroachment, its limiting effect on pine regeneration, and subsequent economic implications; and (3) reluctance of forest administrators to probe the field for fear of spreading confusion in educational work because of the early stand to keep all fire out of the woods, and therefore lose support for protection against wildfire.

The last reason given was a valid one then and to some degree is valid today. Foresters complained about wildfire so long that people finally became aware of fire danger. Foresters then, through the use of prescribed burning, developed into first-class woods burners. It is surprising that the general public accepts prescribed burning as well as they do.

Several prescribed-burning experiments were initiated in loblolly pine stands during the 1940's and 1950's. Much data are now available and the results of prescribed burning can be evaluated on a more scientific basis (Chaiken 1949, Silker 1957 and 1960, Ferguson 1958, among others).

The reluctance of the general public and many applied scientists to accept prescribed burning as a silvicultural technique was due primarily to two reasons: (1) the impression that all fire in the forests was bad, and (2) fire would do irreparable harm to the soil. These objections have been overcome through diligent research on areas burned over by wildfires as well as by controlled fires. Greene (1935), Heyward and Barnette (1934), and Heyward (1936), after years of studying soils in the longleaf pine belt, concluded that burning caused no apparent damage to the physical and chemical properties of the soil. The same conclusions were reached by Moehring, Grano and Bassett (1966) on loessal soils after nine annual prescribed burns were made. A review of the literature suggests there is no serious damage to soil as a result of prescribed burning on relatively flat terrain.

Most foresters in the South now recognize the need for fire to accomplish one or more objectives. It is usually not possible to separate some of the reasons for burning, *i.e.*, hazard reduction will also serve to control understory hardwood, and seedbed preparation can also improve habitat for wildlife. A prescribed burn is normally made for a specific purpose and concomitant results are accepted as additional reward, or in some cases, damage that may be unavoidable. Poor burning technique cannot always be blamed, although it probably is responsible for much loss from fire.

Folweiler (1952) observed that economic aspects have forced many foresters to use fire for various objectives. It seems to be well established that fire is the most economical way of achieving several desired results in silviculture (Chapman and Hall 1947, Riebold 1955, Silker 1960, Lotti *et al.* 1960, Lotti 1962, Cooper 1962, also verbal communication with area foresters). Other methods may be more effective in accomplishing a given job, but they are much more costly (Ferguson 1958). Foresters should therefore inform the public about the difference between wildfire and prescribed burning.

Haig (1950) noted that in recent years evidence has shown a strong natural reversion toward hardwood in the form of dense stands and understories on former pine sites due to our better fire protection and less land clearing. He used statistics for Virginia and South Carolina to illustrate his point. A Virginia forest survey showed two-thirds of the volume of sawtimber in pine; however, two-thirds of the sapling and pole stands were in hardwoods. There seems little doubt that the control of hardwood understories is one of our most serious problems in pine silviculture.

Control of Undesirable Hardwood

The major southern pines are fire subclimax species. Reference to the major southern pines includes the following species: loblolly, longleaf, slash, and shortleaf. They can be perpetuated at the subclimax level of plant succession by the control of competing hardwoods through the use of controlled ground fires (Chaiken 1949). The kill of small hardwoods by controlled fire depends upon species and diameter of trees, season of burning, type of forest humus, heat of fire at ground line, local weather conditions, and frequency and interval of burning (Hodgkins 1958). The heat of fire at ground line depends on the amount and kind of fuel, burning technique, and weather conditions and micro-climate as modified by local cover and topography. A problem in the use of fire in the practice of pine silviculture is that fire is not always predictable even under the best of controls.

Prescribed burning for the control of hardwoods was strongly defended by Chapman in an exchange of letters and comments with Hall (Chapman and Hall 1947). Hall wrote that fire had no place in forestry and that seedlings should be released by mechanical means. Chapman advocated the control of hardwoods with fire in order to give pine a head start. He proposed four points for hardwood control: (1) burn at intervals determined to be appropriate after pine has attained fire immunity, (2) the periodic burning keeps hardwoods small and manageable, (3) repeated fires serve to reduce wildfire hazard, and (4) eradication of understory hardwoods may increase the growth rate of the pine overstory. There seems to be some doubt about the influence on growth of the overstory. Lotti, Klawitter, and LeGrande (1960) found no statistically significant increase or decrease in gro wth increment due to burning.

Single burns are seldom sufficient for hardwood control (Ferguson 1958). Additional burns must be used as needed. After two prescribed burns in 1959 and 1960, Williamson (1964) found a decrease in the overall height of understory hardwoods, but a great increase in the number of stems. On this basis he did not recommend fire for site preparation in pine-oak stands in the Cumberland Plateau. An increase in the number of stems as a result of sprouting is expected at the start of a burning program. Additional burns in the area might have reduced the number of hardwood sprouts following depletion of food reserves in the roots.

Silker's results contrast with most current studies in that he found no appreciable difference in the killback of hardwoods by burning season or frequency (Silker 1960). Other research has shown that a short series of annual or biennial summer burns will practically kill off heavy understories under loblolly pine stands. Approximately 90 percent of southern bayberry (*Myrica cerifera* L.) and similar species were eradicated after four successive annual burns (Lotti 1962, Cooper 1962). Summer burns are evidently more effective in hardwood control, although there are certain objections to summer burning

(Lotti 1960, Stoddard 1962). These points will be discussed under wildlife habitat improvement.

Small hardwood stems up to 1-inch dbh are usually effectively killed by ground fire, but the kill ratio diminishes as stems approach 2 inches dbh, and may be negligible in larger stems. Ferguson (1961), in a study of killback of sweetgum (Liquidambar styraciflua L.), oaks, and pine stems of different sizes, found that killback or complete kill was not totally related to stem size, especially in oaks. In sweetgum the range of killback was 24 percent for 1-inch stems and 15 percent for 3- and 4-inch stems. For oaks the range was 8 percent for 1-inch stems and 3 percent for the 3- and 4-inch stems. Resprouting normally occurred although the recovery rate was about 5 years on good sites and 10 years on poor sites. Thus, repeat fires are needed to control the understory to desirable levels (Lotti 1962). Some research has indicated that annual winter burns accomplish no more than periodic winter burns in that few or no root stocks are killed (Lotti et al. 1960). If this is true, considerable savings could be made by using a minimum number of periodic winter burns.

A fairly comprehensive study comparing summer and winter burns repeated two years apart on different slope types was reported by Hodgkins (1958). He found hardwood mortality much higher for summer burns than for winter burns.

	Percent mortality		
Time of Burn	1-inch trees	2-inch trees	3-inch trees
August	62	52	38
January	46	5	0

By the time of the second burns, reproduction of all hardwoods was more dense on burned sites than on unburned plots, although the results were statistically not significant. New growth was observed to be of sprout origin which coincides with previous studies.

Hodgkins found the net effect on the total hardwood cover, after 2½ growing seasons, was primarily a reduction in average height of the understory. A surprising result of the study was the lack of influence on any of the tree-height classes by different topographic positions. He did find a more extensive cover of shrubs and vines on January burns than on August burns.

Hazard and Fuel Reduction

There is some question about using fire for hazard reduction purposes in any southern pine type other than longleaf and slash. It is much more difficult to obtain a satisfactory prescribed burn in loblolly and shortleaf because of fuel characteristics (Folweiler 1952). Comparatively speaking, it is more of a problem to get a good burn in loblolly; however, winter fires are useful in reducing fuels in young stands, especially needle accumulations hanging on the undergrowth (Lotti 1962). Since the organic material is generally moist in the winter, a burn under proper conditions seldom reaches the mineral soil.

Cummings (1964) presented quantitative evidence that areas prescribed burned received much less damage from severe wildfires than unburned sites. Biswell (1968) supported prescribed burning as a means to diminish the wildfire problem and at the same time aid in efficient management for timber, forage, wildlife, water, and recreation. Cummings believed that prescribed burning was the most important contribution to forest management in the development of forestry in New Jersey. His conclusion was based upon the role of prescribed burning in limiting damage from wildfires.

"Protective burning" was advocated by Bickford (1942) for the flatwoods of the Southeast long before burning was accepted as a forestry practice. His thesis was that controlled burning would remove dangerous fuel accumulations and would create barriers to aid in stopping wildfires.

Some unknown factors which influence the actions of fire in the forest result in variability in the amount of litter and duff consumed by a fire (Sweeney and Biswell 1961, Lindenmuth 1960). The irregularities in areas burned insure spots of varying size where species can survive and maintain themselves even where fire is a characteristic feature of that landscape (Sweeney and Biswell 1961). It is common knowledge that fuel supply, moisture content, wind velocity and direction, topography, and humidity of the air influence fire intensity which in turn affects the rate and amount of fuel consumption. Even where conditions are apparently uniform fire will consume some fuels and not burn others.

Romancier (1960) studied fuel reduction in a 60-year loblolly pine-hardwood stand in Virginia. The stand had a litter accumulation of 4.8 inches (normal leaf and twig fall) plus larger pieces of wood, stumps, down trees, etc. After one winter and two summer burns, the litter layer was less than 2 inches deep. Winter fires served to create more uniform conditions of residual litter within each burning compartment. Winter burns reduced the height and density of the smaller hardwoods and facilitated wind movement through the stands.

It was observed that after the large reduction in fuel by the winter burn subsequent summer burns had little effect upon the relative amounts of fuel in the forest litter which was divided into upper and lower layers. The following tabulation shows the ratio of forest litter under different treatments.

Treatment	Upper layer Percent of total	Lower layer Percent of total
Unburned	23.5	76.5
One winter; 1 summer burn	13.1	86.9
One winter; 2 summer burns	16.5	83.5
One winter; 3 summer burns	14.6	85.4

Stands for the study area were located in poorly drained soils where water remained on one soil type part of the year. A condition such as this would influence litter breakdown as well as the burning conditions.

Dixon (1965) advised that particular care is needed in fuel reduction in very rough areas. A winter fire after at least 0.5 inch of rain is appropriate.

From the evidence it is apparent that forest managers should plan to use prescribed burning when accumulations of excessive fuels build up in valuable pine stands. The burning interval will depend upon the particular stand; however, loblolly pine should be 10 to 15 feet in height for safe burning.

Seedbed Preparation for Regeneration

Fire can create a favorable ground surface for pine seed germination if timed to take advantage of heavy seed crops. McNab and Ach (1967) found that prescribed burning improved stocking and reduced seed requirements for the natural establishment of loblolly pine. Evidence indicated that the beneficial effects of fire treatments persisted for at least one year.

The peak of loblolly seedfall occurs during the first part of November. Lotti (1962) pointed out that 80 percent of loblolly seedfall is completed by December 15 and 90 percent by January 15. The best season to burn, therefore, is the months of September and October (Chaiken and LeGrande 1949, Lotti and McCulley 1951, Little and Somes 1961).

Little and Somes (1961) studied the effects of burning for seedbed preparation in Maryland. They found that 5 years after burning the burned areas had twice as many pines as did unburned areas. The pines that had regenerated on the burned areas were equal to or taller in height than the competing hardwoods.

The chief objective in seedbed preparation is to rid the ground of material that prevents seed from germinating. This material may be slash, leaf litter, grass, shrubs or a combination of materials. The choice of burning method depends on the fuel, time of year, terrain, and weather conditions (Ferguson 1958). An important point is that reproduction of loblolly pine will not ordinarily survive if it originates under dense hardwood sprouts two or more years old (Chapman 1952). As mentioned earlier, this condition can be prevented by burning in early fall (preferably in September or October) of a good seed year to control the hardwoods under 2 inches dbh.

Experience with prescribed burning indicates light winter fires used in conjunction with other treatments can be used advantageously to favor loblolly pine reproduction. Two winter fires followed by poisoning of the larger surviving hardwoods prior to harvest cutting should greatly favor establishment of pine seedlings and their subsequent dominance in the new stand (Little and Somes 1961). One winter burn followed by three summer burns was a very effective method of seedbed preparation and in controlling hardwoods for a period up to four years (Trousdell and Langdon 1967). Lotti (1962) recommended summer fires four or five years before the harvest cut to prepare the area for natural regeneration. Doubtlessly, the burning program for each individual forest must be evaluated on the basis of management objectives.

It seems that summer burns are unnecessary if a proper program of winter burning is followed. There are occasions when the hardwood understory gets out of control and summer burns may be used along with other cultural treatments. It is general knowledge that stems too large to be killed by fire must be cut, poisoned, or girdled if their control is desired.

Improvement of Wildlife Habitat

Wildlife biologists have recognized the advantages of fire under the right conditions in southern pine stands. The increase in pine seedlings and herbaceous cover as well as the production of more succulent shrub stems following controlled burning resulted in increased deer browse (Cantlon and Buell 1952). Lay (1956) and Miller (1963) supported this position. Lay found that burning did not affect the total forage production significantly but changes the type distribution and size of the understory vegetation. He recorded the following changes in weight. Yaupon (*Ilex vomitoria* Ait.) and holly (*Ilex* sp.) decreased 68 and 90 percent, respectively, while yellow jessamine /*Gelsemium sempervirens* (L.) Ait.f./, *Viburnum* sp., and herbaceous forage increased 23, 515, and 376 percent, respectively. The average height of understory hardwoods ranged from 9 to 12 feet at the beginning of the test burns. After the second burn the height of the understory ranged from 1.8 to 5.8 feet. Lay considered the species composition of the vegetation the most important criterion in the evaluation of browse for wildlife.

Lay (1957) emphasized that burning, particularly in the early spring, gave maximum increases in seven plant nutrients. The effects of burning on quality of browse was usually beneficial. According to Lay, forage quality was more limited on a year-round carrying capacity than was forage quantity. He listed yaupon, sweetgum, and American beautyberry (Callicarpa americana L.) as showing the greatest nutrient changes after burning. Those with the least change were water oak (Quercus nigra L.), muscadine (Vitus sp), and Viburnum sp.

Cattle grazing in woodland pastures make heavy use of some browse plants in competition with deer, probably because of the palatability of the browse species involved (Lay 1957). In winter months the carrying capacity for cattle and deer appears to be somewhat correlated with the amount of desirable evergreen and semi-evergreen species present. The competition for forage between cattle and deer is especially pertinent in areas where woodland grazing of cattle is commonplace.

Ecological studies have traced the successional pattern following prescribed burns. Forbs generally increase in the first growing season after the fire but decrease as grass and woody plants take over. Shrubs and woody vines as a class will establish themselves after the fire in competition with existing trees (Hodgkins 1958). It is known that the understory hardwood sprouts give way slowly to tree seedlings. Competition from the hardwood sprouts effectively prevents the starting of tree seedlings later than the first season after the burn.

The interval between burns depends upon the owner's objectives. A good average interval often suggested is to burn every five years. This type of program of regular burning is beneficial to wildlife, especially deer and turkey. Riebold (1955) noted that the frequent reduction of hardwoods to sprouts by winter fires produced an enormous amount of browse for deer. It also made it easier for quail and other game birds to scratch in the mineral soil and operate on the forest floor.

Stoddard (1963) considered fire so important in quail management that he called them "fire birds." He observed that both quail and turkey flocked to burned areas in the pine forest habitat.

Wildlife conservationists are firmly opposed to summer burning (May to August) even for seedbed preparation (Smith 1948, Stoddard 1962). The "normal" burning period (September to October) for seedbed preparation should be after most young birds and mammals have developed sufficiently to escape the flames. Also, this is the best time to catch the seedfall of desirable species. Stoddard was critical of the recent publications recommending summer burning. He indicated the practice of summer burning could start a conservation battle between wildlife enthusiasts and foresters.

More (1956) conducted a study of the effects of burning on quail food in the upper Coastal Plain of Alabama. He found that the frequency of occurrence and percent cover of the herbaceous plants to be highly variable between plots of each treatment. He found that beggar lice (*Desmodium* sp.), spurge (*Euphorbia corollata* L.), and tragia (*Tragia urticifolia* Mich.) showed the greatest response to fire treatment. Woody species such as shining sumac (*Rhus copallina* L.), smooth sumac (*Rhus glabra* L.), persimmon (*Diospyros virginiana* L.), oaks (*Quercus* sp.), and hickories (*Carya* sp.) had the greatest frequency of occurrence on winter burned plots. Moore admitted that too little time had elapsed after treatments to get the best possible results for his study.

Moore and Manney (1962) studied deer browse plants in loblolly pine forest on the Piedmont in Georgia. They classified their findings into the commonly used categories of preferred, staple, emergency, stuffing, and miscellaneous food plants. The frequency distribution by browse preference classes was as follows: preferred -- 7.7 percent, staple -- 19.2 percent, emergency -- 20.4 percent, stuffing -- 16.4 percent, and miscellaneous -- 6.3 percent. The classification of an individual species as deer browse largely depends upon the geographical location under consideration (Halls and Ripley 1961).

Cushwa, Brender, and Cooper (1966) measured the response of herbaceous vegetation to prescribed burning on the Piedmont. Some of the leading plants in order of abundance on plots were: panic grass (*Panicum* sp.), beggar lice, bush clover (*Lespedeza* sp.), milkpea (*Galactia* sp.), and senna (*Cassia* sp.). They found significantly more plants in burned areas than in unburned areas, but there was no significant difference between burning treatments or between slope positions. They could not explain some of their findings such as more legumes on plots burned with strip headfires than on those plots burned by backing fires.

Czuhai and Cushwa (1968) summarized prescribed burning work on the Piedmont National Wildlife Refuge. They emphasized the lack of specific information on effects of burning in the area; however, they stated the following conclusions: (1) herbaceous vegetation and sprout growth are greatly increased by burning, (2) larger blocks of land are more economical to burn, (3) hotter fires are more effective in increasing gamebird food plants such as Desmodium sp. and Cassia sp. than are cooler fires, (4) prescribed burning is an economical means of hardwood control and reduction of wildfire hazard, and (5) prescribed burning had not accelerated erosion noticeably.

Lemon (1967) considered several past studies made on the Coastal Plains and noted there was a range of 6.4 to 41.3 percent more herbage produced on burned areas than on unburned areas. He presented the following factors which might have increased herbage growth: (1) higher soil temperature in the spring and early summer contributed to earlier growth on burned sites; (2) soil fertility, especially nitrogen, might have been increased; and (3) removal of dead litter and shoots and foliage of herbaceous plants increased growth. Devet (1967) corroborated Lemon and added that burning reduced the basal area of noncommercials understory species.

Prescribed burning results in certain known changes in the understory vegetation. Forest land managers must be cognizant of the vegetation changes due to burning to adequately plan for the improvement of wildlife habitat. Dixon (1965) summarized the results of burning for improvement in wildlife habitat as follows: (1) increases deer forage by keeping hardwood sprouts short, tender, palatable, and abundant; (2) reduces undergrowth which shelters predators; (3) opens the woods so that turkeys can get off the ground; (4) results in more herbaceous plants, especially legumes, for both large and small game birds, (5) moves turkeys from one area to another; and (6) exposes mineral soil for quail. No wildlife conservationist can rightly object to a program which accomplishes these results.

Improvement of Grazing

The practice of late winter burning in the South for cattle pasturage is one of long standing. Wahlenberg, Greene, and Reed (1939) stated that grazing on wild lands of the South in the absence of burning had yet to be proved practicable. In order to test the effects of fire and grazing they initiated a study in which four burning and grazing treatments, burned annually-ungrazed, burned annually-grazed, unburned-grazed, and unburned-ungrazed, were used to test the quality and quantity of forage. They found that annual winter burning maintained a more favorable composition, quality, and quantity of forage than did exclusion of fire. The smothering due to pine litter and accumulated dead grass retarded the growth of native grasses and legumes and reduced the number of plants per acre. The largest number of legumes per acre occurred in the burned-ungrazed areas, and the smallest number was on the unburned-ungrazed areas. Improvement in forage conditions was reflected in greater seasonal gains of cattle in burned areas. Cattle grazed on burned areas gained 37 percent more weight than those grazed on unburned areas. These findings did not reveal any serious soil degradation due to burning and grazing. Burned-over soils exhibited slightly more favorable chemical characteristics and some unfavorable physical characteristics compared to unburned soils. Based on the results of the study, they recommended the use of periodic burns rather than no burning or annual burning.

Lemon (1943) studied growth patterns, especially of herbs, in prescribed burned areas of longleaf pine forest in Georgia. He examined the phenology of plants that reproduced in burned areas. His findings showed that burned areas produced 6 to 41 percent more herbaceous foliage than areas protected from fire for 8 or 9 years. It was characteristic that a large group of "fire followers" came in immediately after burning but were largely gone in a few years. Results of his research are quite applicable to grazing since the emphasis was on grasses.

In a later paper, Lemon (1949) classified the understory vegetation into categories as consumed by cattle. He found 93 percent of the diet of the cattle was composed of grasses and grass-like plants, 3 percent was broadleaf herbs (on forbs), and 4 percent was composed of shrubs and hardwood trees. He concluded that grazing conditions in the native ranges of the southeastern Coastal Plain are improved by careful prescribed burning during the winter months.

Hilmon and Hughes (1965) summarized much of the pertinent research completed or in process at that time on grazing in prescribed burned areas. They noted the marked decline in total plant cover with fire protection over a period of years. It was also pointed out that bluestem grasses (Andropogon sp.) decline under conditions of annual burning. Between the two extremes of no burning and annual burning, 3- and 4-year rotation burning studies have indicated no significant change in botanical composition and average yield of forage.

Weaver (1959) concluded that prescribed burning in ponderosa pine (Pinus ponderosa Laws) forest of the Southwest had benefited grass by thinning dense pine reproduction and by reducing certain associated competing species. In addition, burning had an apparent fertilizer effect.

Understory Species as Plant Indicators

Many uses have been made of the understory vegetation as indicator species. It is readily recognized that the numerous environmental variables which influence vegetation make it impossible for any plant species to predominate over a very large region.

Probably the most extensive use of plants as indicators is that of differentiating climatic types. The Koeppen classification is the most widely known and was based upon vegetation in the original derivation. Muller (1937) distinguished five climatic types in northeastern Mexico through the use of vegetation types and growth forms. He considered the vegetation of a given area an adequate expression of climate.

The most comprehensive review on the subject of plant indicators was by Sampson (1939). He divided the use of indicators into the following topics for review purposes: (1) plant guide to land use problems, (2) range (pasture) indicators, (3) forest and soil indicators, and (4) plant indicators and chronology (climatic change). He noted plant indicators could be considered as a cause-effect relationship, where the effect is taken as a sign of the cause. All plants are a measure to some extent of their environment, but only a few are so restricted by growth conditions to be useful. Single species seldom hold such a prominent position that it can be used as a reliable indicator. Sampson concluded that groups of species might be relevant as indicators in many areas. This is the most widely accepted position at present.

Korstian (1919) stated that no one criterion should be used at the exclusion of other factors in the determination of site quality, since each factor might serve as a check on the others. He indicated that due consideration should be given to native shrubby and herbaceous vegetation in the classification of the potential productivity of forest lands. Korstian further noted that lower vegetation might be important in explaining the presence or absence of tree growth on certain areas.

Kelly (1922) investigated the long known relationship of vegetation and soil types. He found soil acidity to be the most influential soil factor in causing variation in plant species. On the basis of pH, plant species could be assigned values and used as indicators.

Holman (1929) supported Korstian's position in that he found a close relationship between ground flora and the overstory in Canadian forests. Hazard (1937) observed five plant indicators under eastern white pine (*Pinus strobus* L.). The presence of the five plants depended upon soil moisture, pH value of the soil, the crown density, and age class.

In a study of the importance of understory vegetation as indicator plants under eastern white pine in New Hampshire, Stanley (1938) found that soil moisture was more important than light in regulating vegetation on the forest floor. He found no correlation between light intensity and degree of cover of the understory vegetation. In general, better communities occupied the less acid soil. He suggested the use of communities to supplement other criteria in determining site quality for eastern white pine in the Northeast. He concluded that caution should be used where understory vegetation is complex and the forest history has had a varied background of management.

Westveld (1952, 1954) noted the concept of plant indicators recognizes that plant communities have definite arrangements according to biological law. He stressed that the use of certain indicator plants provides a basis for identifying site qualities in terms of natural forest types but recognized the need of supplemental information such as tree height, tree associations, soils, and landforms. Westveld believed radically disturbed areas defy classification for an indefinite period.

Rowe (1956) contended undergrowth could be used for stand description, interpretation of successional trends, regeneration possibilities, and site quality among other things. He emphasized it is much easier to read from forest plants than to do the back-breaking work of studying soil profiles. Rowe was convinced the principal factor controlling the structure of understory vegetation is light. While several plants showed wide moisture tolerance, most plants showed a preference for a particular moisture regime. A prominent stratum of undergrowth was frequently a good index of stand density, and in some instances, a pronounced shrub stratum indicated an understocked forest, while a needle cover suggested overstocking.

By assigning values and establishing an understory indicator index, Hodgkins (1961), working in Alabama, found a high correlation between site index and his understory indicator index. Consistency held in application of the plant indicator scale to various plots by different students.

Bradley (1963) was only partially successful in his modification of Hodgkin's work in using the understory vegetation as a means of predicting site index for loblolly pine in southeastern Louisiana. Bradley declared that his indicator index must be applied in undisturbed areas (no burning, cutting, or stumping for a number of years). Undisturbed areas in the South, particularly those unburned, are difficult to locate.

Since burning on a prescribed basis is so important to southern forestry, it would be very helpful if certain understory plants could be used as indicators to ascertain the proper burning regime. Because of the many variables which influence understory growth, it seems unlikely that plants could serve as indicators over a wide area of different moisture and soil conditions. In prescribed burning experiments in East Texas, Silker (1957, 1960) noticed that certain species such as American beautyberry, *Vaccinium* sp., sassafras /*Sassafras albidum* (nutt.) *Nees*/, and sumac (*Rhus* sp.) often had low mortality rates after prescribed burning. He suggested these species might be used as indicator plants to show control of other undesirable hardwoods in the understory. Some or all of the species mentioned may be useful in southeastern Louisiana.

METHODS AND PROCEDURE

General Description of Area of Study

The study area is centrally located in the "Florida Parishes" of southeastern Louisiana. Sites for study were selected in the three parishes (counties) of Livingston, St. Helena, and Tangipahoa (Figure 1). These parishes are representative of the physical and cultural landscape in this region of Louisiana.

The climate is classified as Humid Subtropical (Cfa) and is characterized by mild winters and warm to hot summers. Relative humidity averages high throughout the year. While precipitation is considered adequate and well distributed in all months of the year, wide variations may occur in any given month or year. The combination of high precipitation and mild temperatures makes this climate the most productive for forest growth in North America.

Data for three representative stations near the forest stands studied are shown in Table 1. Interpolation provided an average of 58.5 inches annual precipitation for the study area. Precipitation was considered a constant for purposes of analysis in this study.

Two general topographic regions are evident in the area: (1) the northern or Pleistocene dissected upland belt which is 10 to 20 miles wide, and (2) the southern low-lying alluvial terraces and flood and deltaic plains (Woodward and Gueno 1941). Streams have abnormally high gradients as a result of continuous coastward tilting of the earth surface.

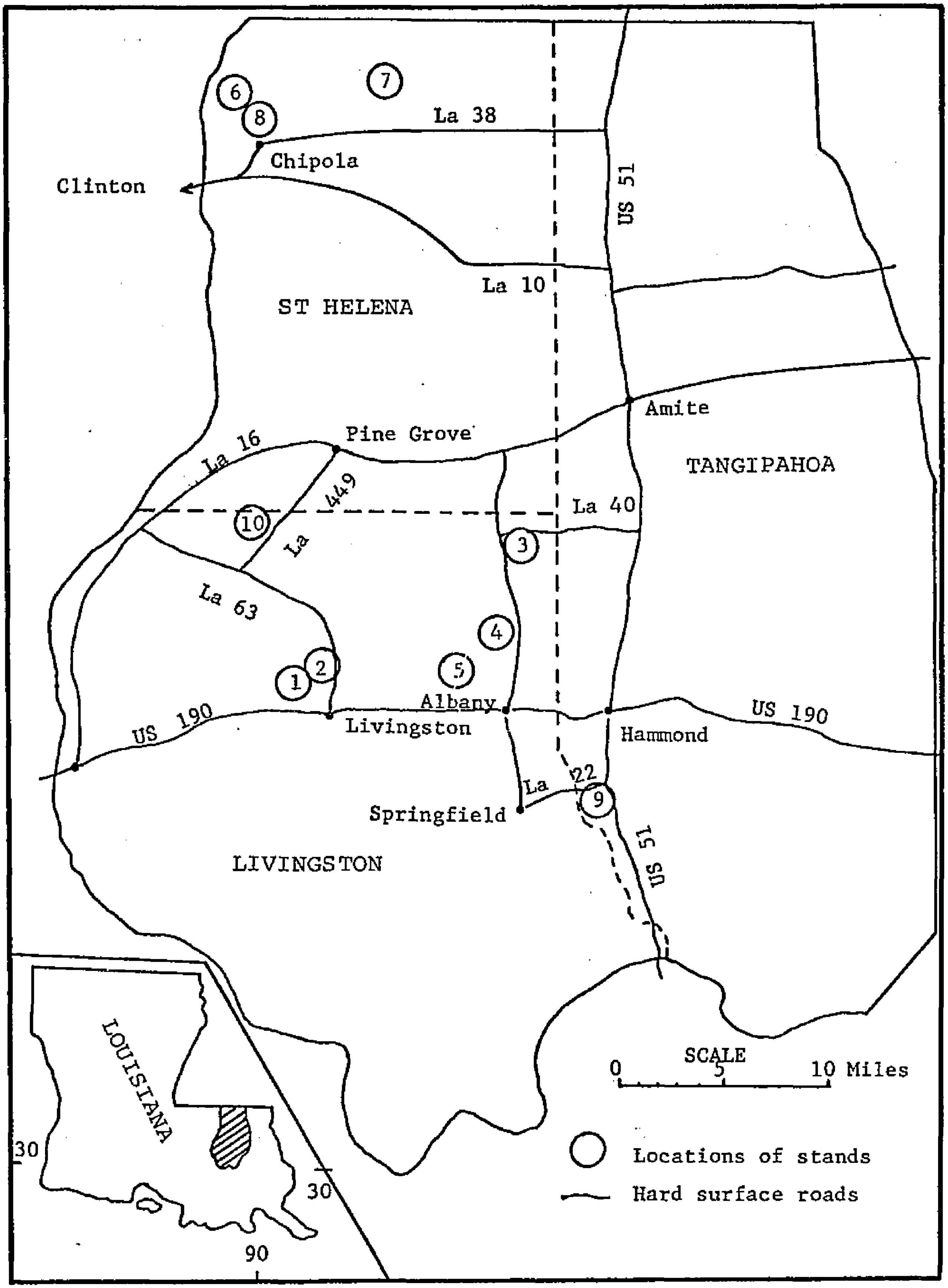


Figure 1. The study area.

Table 1. Climatic data for the study area of southeastern Louisiana[a]

Month	Amite			Clinton			Hammond		
	Temp.[b]	Prec.[c]	Prec.[d]	Temp.[b]	Prec.[c]	Prec.[d]	Temp.[b]	Prec.[c]	Prec.[d]
Jan	51.1	4.10	0.62	52.3	4.39	1.40	53.6	3.35	1.22
Feb	54.3	6.05	4.68	55.1	5.57	5.90	56.3	6.15	5.24
Mar	59.3	4.50	6.01	59.3	5.23	6.16	60.4	5.04	6.81
Apr	66.8	5.62	10.31	67.1	4.62	7.42	67.8	5.69	9.58
May	74.1	4.86	5.88	74.0	4.96	7.32	74.4	5.54	7.19
Jun	79.7	5.58	1.25	79.7	5.21	0.69	80.2	4.40	0.63
Jul	82.1	8.31	7.82	81.7	6.64	8.69	82.1	7.25	11.69
Aug	81.5	5.36	3.86	81.4	5.34	2.23	81.9	4.57	4.64
Sep	77.5	4.88	2.31	76.6	3.55	2.98	78.0	4.67	3.15
Oct	67.3	2.22	4.32	66.3	2.57	5.41	68.3	2.39	6.20
Nov	57.0	4.41	1.73	57.1	3.80	0.68	58.6	4.15	0.62
Dec	51.5	5.40	4.88	53.0	6.07	6.29	54.0	5.02	4.20
Year	66.9	61.39	53.67	67.0	57.95	55.17	68.0	58.22	61.17

Weather stations: Amite, Clinton, Hammond.

[a]Source: For period 1951-1960, Weather Bureau, U. S. Dept. Comm. 1964; For 1969, Louisiana State climatologist, unpublished data, 1970.

[b]Average temperatures in Fahrenheit degrees for a 10-year period.

[c]Average precipitation in inches for a 10-year period.

[d]Total precipitation in inches for each month and the year 1969.

Due to the complex history of this area (the Mississippi Valley) throughout the Pleistocene period (ice age) and the degradational conditions during the past several thousand years, many efforts have been made to correlate the alluvial surfaces (terraces) and relate them to the various stages of continental glacier waxing and waning (see especially Fisk et al. 1938 and Russell 1940). The tremendous amounts of water-transported materials resulted in extensive sand and gravel deposits along the larger streams (Woodward and Gueno 1941).

The area is characterized by relatively low relief. The average elevation is only a few feet above sea level in the southern parts of Livingston and Tangipahoa Parishes and exceeds 350 feet in only a few locations of northern Tangipahoa and St. Helena Parishes. Drainage is via south-flowing streams along which the most obvious relief differences are visible. The almost level land of the southern portions changes gradually to rolling or undulating terrain in the north.

Soils are predominantly in the flatwoods and Mississippi terrace and loessal-hills types. The flatwoods soils developed from Pleistocene and Tertiary materials. Mississippi terrace and loessal hills soils developed from late Pleistocene and Recent sediments and from silty and sandy materials of the Pleistocene, respectively (Lytle and Sturgis 1962).

The cultural landscape varies somewhat in the three parishes. Rural conditions have been examined in detail by Wright (1956) and by Newton (1967). Wright studied the extension of hill culture into Louisiana and found one of the core areas in St. Helena Parish. This hill culture extended into the other two parishes under study. Newton carried out a micro-investigation of the agricultural conditions in St. Helena Parish. He found three agricultural types: (1) the general farm, oldest and least specialized; (2) the stock farm, the earliest specialization in agriculture; and (3) the dairy farm, a response to urbanization and evolution of transportation. He noted that the stock farm was most widespread. Open range grazing is practiced in all three parishes and many people own at least a few head of cattle. Newton (1967) observed that large parts of each farm were used for grazing and forage.

Crops grown for subsistence purposes or for cash income included corn, cotton, peas, sweet potatoes, and beans. In Tangipahoa and Livingston Parishes strawberries and peppers were also important as cash crops. A strong agricultural base was present in the three parishes, but statistics by the Public Affairs Research Council (1965) revealed a different emphasis on the sources of cash income from the farms. Dairy products accounted for 70.9 percent of total farm income in St. Helena and 52.0 percent of the total in Tangipahoa. The major source in Livingston Parish was poultry and poultry products (62.7 percent of total farm income).

The emphasis on forest production might be reflected in the number of primary wood users in each parish. The users of raw forest materials varied from creosote treatment operations to a large plywood plant. St. Helena had two primary wood uses, Livingston had five, and Tangipahoa led with 12 (Gunter and Klein 1968).

Land-ownership patterns, especially for that land classified as forest or woodland, are significant in understanding the utilization and management of forests. Siegel (1960) found some notable differences in ownerships over 15,000 acres. In Livingston and St. Helena Parishes three owners in each parish controlled 42 percent and 39 percent of the total forest land, respectively. In Tangipahoa Parish one owner with 5 percent of the total forest land was listed. The ownership patterns were similar in many respects; however, there was a lack of ownerships in the intermediate size class (5,000 to 15,000 acres) in St. Helena Parish. In that particular Parish the forest land was about equally divided between large and small holdings.

The importance of woodlands for grazing and forage is emphasized when the percentage of land area classified as woodland in each parish is known. The approximately 371,000 acres classified as woodland in Livingston Parish is 87 percent of the total land area. The 222,000 acres in St. Helena Parish is about 83 percent of the total land area. Tangipahoa had a larger percentage of cleared land due to the emphasis on truck farming and particularly strawberry production. The 397,000 acres classified as woodlands is about 77 percent of the Parish total.

Forest cover in the tri-parish area might be classified as pure pine except for that along streams and in the southernmost parts of Livingston and Tangipahoa parishes where mixed pine-hardwood and pure hardwood stands are found. Some of the best loblolly pine stands in the United States are found in Livingston Parish.

Management has been applied by the industrial paper companies and some of the larger landowners for several years. Prescribed burning was started on a large scale about 20 years ago. Prior to that time, many woods were burned, either purposely or by wildfires. Almost all of the forested land is now burned for grazing purposes, for hazard reduction, or for control of understory hardwoods.

Study Sites

Pure stands of even-aged loblolly pine were chosen on the basis of the completeness of burning records. Following consultation with foresters and landowners approximately 25 areas were field checked in the process of choosing appropriate stands for study. Ten were chosen and sampled (Figure 1). Areas as nearly comparable as possible in relief, soil types, timber stand density, age, and site index were selected. Relief of the stands chosen for study varied little. The primary difference was one of soil drainage or soil type. Surface relief ranged from level to nearly level. Surface slope did not exceed 3 percent in any stand. After data were collected in the actual sampling process, it was found that the preliminary survey and selection of stands proved to be sound in most respects.

Cultural treatments such as burning frequencies, total number of burns, thinnings of the overstory, and other data which could not be obtained by measurements and observation in the field were obtained from foresters responsible for managing the land and from landowners.

Stands were divided into three categories for purposes of analysis: burned annually, burned periodically, and unburned for at least

20 years. The stand ages were in the 25- to 35- and 40- to 50-year classes. Both age classes were represented in each of the three treatments. Soils were grouped into three classes on the basis of internal drainage. These three soil drainage classes were: poorly drained flatwoods soils, somewhat poorly drained terrace soils with fragipans, and moderately well-drained loessal hills soils. A complete description of the stands is presented later.

Field Measurement Techniques and the Collection of Data

Once the study sites were field checked and the stands then selected for sampling, a technique was evolved for measuring the vegetation. The vegetation was classified as overstory, midstory, and understory. Overstory included all pine at least 2 inches in diameter breast height (dbh) and over 8 feet tall and all hardwood at least 4 inches dbh and over 8 feet tall. The midstory included trees and shrubs over 8 feet tall but not considered part of the overstory. It was assumed that well-managed stands regularly burned would not have appreciable midstories. The understory comprised all plants less than 8 feet in height, including grasses and forbs. The understory was grouped into three height classes: (1) less than 3 feet, (2) 3 to 6 feet, and (3) 6 to 8 feet. There is no general consensus among authorities of understory height limit so 8 feet was arbitrarily chosen.

A segmented line-belt quadrat modified after Woodin and Lindsey (1954) was used for sampling the understory (Figure 2). As Larsen (1959) pointed out, the line-belt method combines favorable aspects of the individual line and belt techniques. Measures of frequency

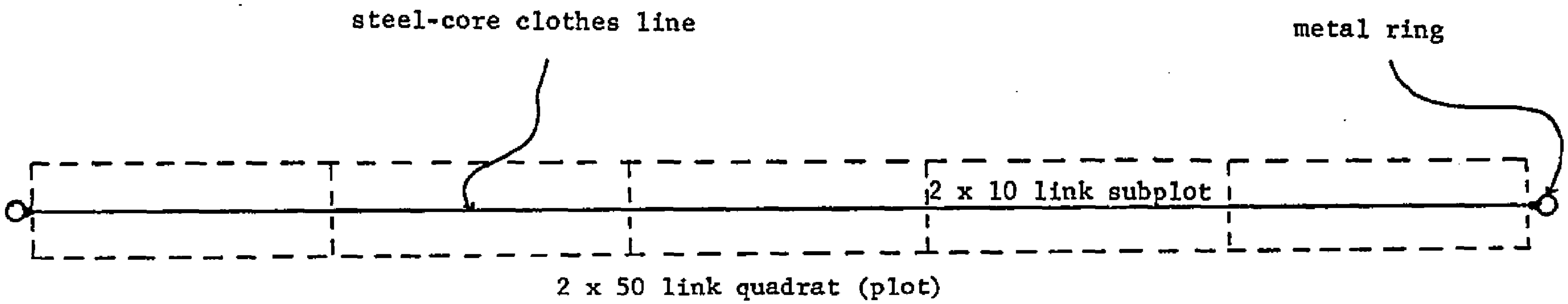
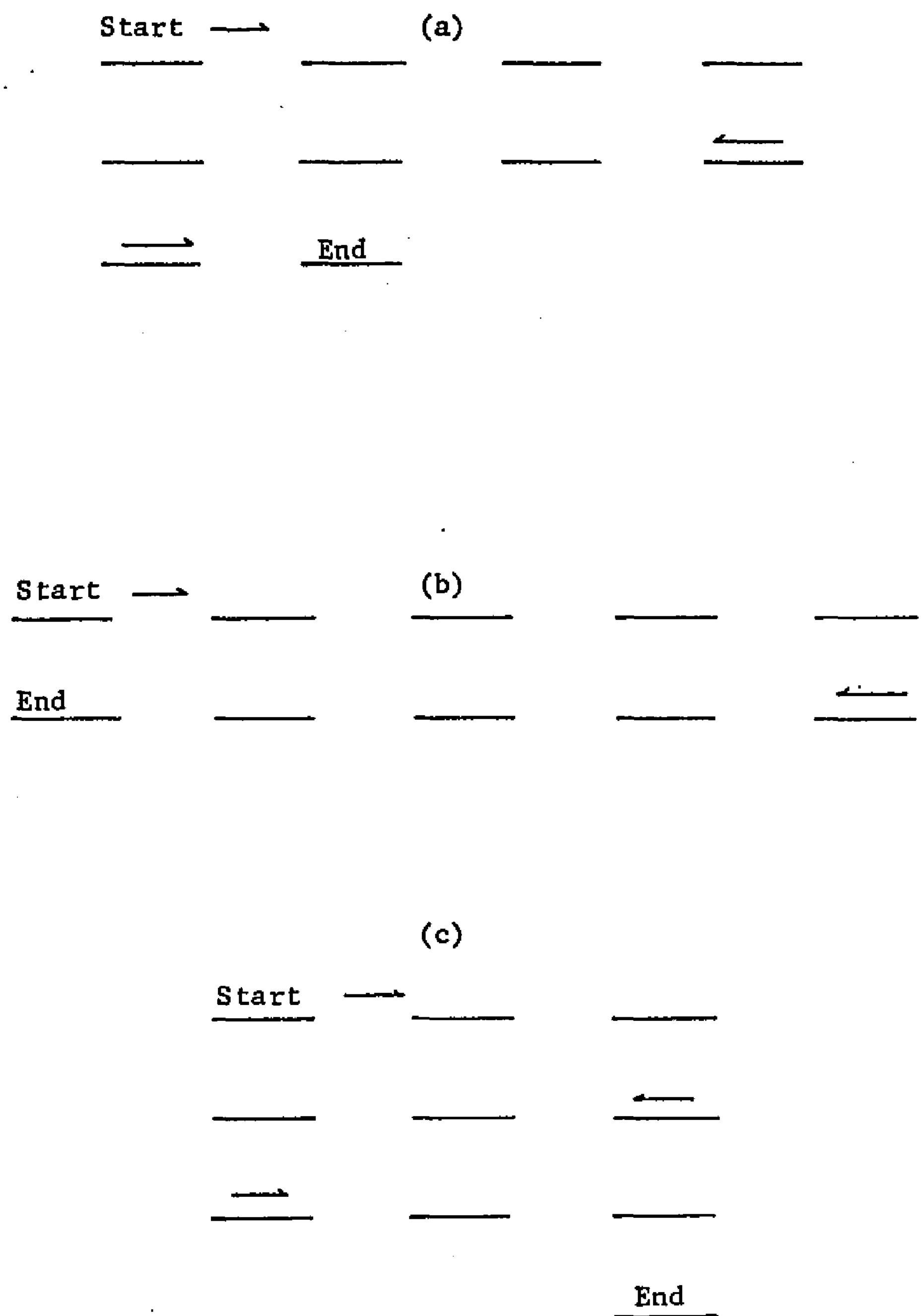


Figure 2. Segmented line-belt quadrat used in sampling understory vegetation. A link is equal to .66 foot.

distribution and cover percent are more reliable when the line-belt quadrats are segmented.

Ten milacre quadrats (2- x 50-link plots segmented into 2- x 10-link subplots) were taken in each stand (a link is equal to .66 foot). The arrangement of quadrats (plots) was based upon the size and shape of the stand to be sampled and upon the location of the first plot which was chosen at random. Ten cards, each of which had a distance value expressed in 50-link units, were used in the selection method for the first plot. The first card was assigned 100 links, the next card 150 links and continuing through the last card which was 550 links. At each stand a card was selected, its assigned value was noted, and the card was returned to the stack. This same procedure was repeated so that two distance values were available for use in locating the starting point of the first milacre quadrat. Roads or fences were used to facilitate the procedure. The first distance value which had been selected was measured off by pacing along a road or fence from a predetermined starting point (fence corner or road intersection where available). The second distance value selected was paced off into the stand at a right angle to the first line. The first of the 10 quadrats was started from that point.

A systematic arrangement of plots was used after the first plot was located. Figure 3 illustrates the different patterns of quadrats used in the study. The layout in Figure 3a was used in stands 1, 3, 6, 7, and 10. Figure 3b illustrates the arrangement used in stands 4, 5, and 8. Figure 3c shows the pattern for stands 2 and 9.



Note: Plots and distances between plots are not to scale.

Milacre plot
Direction of movement

Figure 3. Arrangements of milacre plots used in sampling.

Spacing between the milacre quadrats varied from 2 to 4 chains depending upon the size of the area chosen for sampling in each stand. In each case the transects were established by compass and the distances between plots were measured by pacing. The objective was to obtain a representative sample from each stand.

A steel-core clothes line 50 links in length with rings attached at each end for stakes was marked in such a way so as to be divided into five equal segments. This line could be laid out rapidly and stretched tautly between two aluminum tent stakes pushed into the ground. A 1 x 1-inch wood strip 2 links long was cut and grooved across the middle. This 2-link strip was then moved along the taut clothes line as shown in Figure 4. Every woody stem which was contacted by the 2-link strip was tallied by height class and by subplot. The presence of herbaceous vegetation in each subplot was recorded by species or by genera. Individual stems of herbs were not tallied.

An occular estimate was used to determine the percent of the ground covered (cover percentage) by overstory, understory, and grass. Three classes of cover percentage were used: (1) 0 to 33 percent, (2) 34 to 66 percent, and (3) 67 to 100 percent. As the sampling moved along the 50-link line, the overstory was observed at every 10-link market and the percent cover estimated. The same procedure was followed for the understory and for the grass cover alone. It was anticipated that a measure of grass cover might be useful in indicating grazing potential.

Overstory pines and hardwoods within sample plots were measured for dbh, height, and age so as to obtain a stand description of each

Figure 4. Method used to locate understory vegetation within sample quadrats.

study site. Such data were collected from trees within 33- by 66-link plots established along the same compass lines as the understory quadrats. The dbh measurements were accomplished by the use of a diameter tape. Average age of the dominant trees was determined by increment borings. Tree heights were measured with a Haga altimeter and a 100-foot metallic tape (Figures 5 and 6). Site index for each stand was determined from curves based upon height growth data in U. S. Dept. Agr. Misc. Pub. No. 50, revised according to Coile and Schumacher (1953). When measurements of the pine were made, the lower portion of the boles was examined for obvious fire damage.

Data were recorded in the field on specially constructed tally sheets. Since the herbaceous species encountered in the field could not be anticipated, it was not practical to use IBM cards or code sheets during the actual sampling. Each plant was written down on the tally sheet the first time it was encountered in a given milacre plot. Stems of shrub and tree species were then tallied in each succeeding subplot by the dot method. A check mark (✓) was used to indicate the presence of vine or herbaceous species by subplots.

Several plant guides or illustrative publications were used for field checking familiar, but sometimes questionable, species. These included Brown (1945), Louisiana Cooperative Extension Service (1969), Harrar and Harrar (1962), Grelen and Duvall (1966), and Halls and Ripley (1961). Unknown herbaceous vegetation was collected, given an identifying number, and placed in a field press for later identification by a plant specialist. These plants were then mounted and subsequently used in the field.

Figure 5. Measuring diameter of a tree with a diameter tape.

Figure 6. Tree heights obtained with a Haga altimeter and a 100-foot metallic tape.

Collection of plant data was carried out during the months of September and October 1969. A two-man crew proved to be quite efficient. One man moved along the quadrat, identified plants, and enumerated while the second man observed the identification and tallied (Figure 7).

Soils were field checked and typed by a soil scientist from the Agronomy Department at Louisiana State University. There were six principal soil types in the 10 stands. Complete soil descriptions are presented in Appendix C. For purposes of analyzing the influence of soil on the understory vegetation the six soil types were arranged in three fairly distinct drainage classes: Class 1 is poorly drained flatwoods soils (Leaf, Springfield, and Calhoun silt loams), Class 2 is somewhat poorly drained terrace soils with fragipans (Stough very fine sandy loam and Olivier silt loam), and Class 3 is moderately well drained loessal hills soil (Providence silt loam). Since precipitation and temperature were similar in all the stands, soil drainage was deemed the most significant reason for grouping the soil types.

Analysis of the Data

When the field work was completed, the data were organized and transferred to IBM cards for computer analysis. Analyses of variance and orthogonal comparisons were calculated in order to detect causes in variation among the stands for selected woody species. The following model was used in the analyses of variance:

Figure 7. Inventorying understory vegetation within a sample quadrat.

Source of variation	d.f. (degrees of freedom)
Total	499
Stands	9
	1
	1
	1
	1
orthogonal comparisons	1
	1
	1
	1
	1
Plot/stands	90
Subplot/plots/stands	400

Sums of squares and mean squares were obtained by computer. Orthogonal comparisons using the following formula were derived on an electric calculator:

$$Q^2 = \frac{\left[M_1T_1 + M_2T_2 + \ldots + M_kT_k\right]^2}{n\left[M_1^2 + M_2^2 + \ldots + M_k^2\right]}$$

where: M_1 = constant multiplier for the ith treatment

T_2 = sum of the observation for the ith treatment

n = number of observations per treatment

Q^2 = individual degree of freedom sum of squares.

Since light has an influence on plant growth, a correlation analysis of the overstory cover and understory vegetation was computed and expressed in r values. To complete the analysis, simple mathematical tabulations were used to present information on the structure and composition of the understory.

Chi-square tests were used for selected herbs in an effort to detect some pattern of distributional influences. Computations for chi-square were by computer analysis. Frequency distributions for selected species and those species that had statistically significant chi-square values are shown in Appendix B.

All plant species encountered in the study are listed in Appendix A. Scientific and common names of shrubs and trees are according to Little (1953). Names of vines and herbaceous vegetation are based upon Radford, Ahles, and Bell (1968), except for a few common names from Fernald (1950).

RESULTS AND DISCUSSION

Presentation of Results

The structure and composition of the understory vegetation are of utmost importance to the manager of forest land, regardless of the objectives of management. Prescribed burning, a practical technique widely used in southern forestry, results in an alteration of vegetation under the forest canopy. This study examined 10 stands of forest, seven of which had been prescribed burned on either an annual or periodic basis, while the remaining three stands were unburned for a period of at least 20 years. The soils on which these stands were located were grouped into three distinct soil drainage classes: (1) poorly drained flatwoods soils, (2) somewhat poorly drained terrace soils with fragipans, and (3) moderately well-drained loessal hills soils. Two overstory age classes, 25- to 35-year-old and 40- to 50-year-old, were represented. The data collected during the course of study were organized and are presented in Tables 2 through 22. Management practices varied with land ownership and location. Generally, the large paper companies followed 5-year cutting cycles usually beginning at age 20 with low thinnings of a light to moderate intensity (trees normally marked were in the overtopped and intermediate classes). The silvicultural information that was available is presented in the following discussion of individual stands.

Stands Burned Annually

Stand 5. -- Three stands, stand 5, stand 2, and stand 7, had been prescribed burned each year (Table 2 and Figure 8). Stand 5 is an area of approximately 500 acres located in Livingston Parish and is owned by the International Paper Company. The area sampled is the W½ SW¼ Sec. 10, T 6S, R 6 E. Observation indicated a natural stand of loblolly pine on an area that had been in cultivation at an earlier period.

There was considerable variation in the ages of groups of trees and drainage conditions over the 500 acres, so careful selection of an area for study was necessary. The site chosen was comparable in surface drainage and tree size to two other stands selected for study. The average age of the stand was 31 years. Soils are of drainage class 2. All stands in the entire study were in areas of cattle grazing, but this particular stand appeared to be the most heavily grazed. One thinning for pulpwood was carried out in 1963. Observation showed that a combination of prescribed burning and fusiform rust had caused obvious damage to boles of overstory pine trees. Since this type of damage was limited to this particular stand, it will be discussed later. This stand had been burned annually for the past 10 years. The scarcity of vegetation in the understory is apparent from scrutiny of Tables 3 and 4. The 10 shrub and tree species tallied in the understory of this stand were not only the fewest found in any stand, but the total stem count was unusually low compared to other prescribed burned areas. Study of the data shows that about 32 percent of the stems were

Table 2. Characteristics of stands selected for study

Stand number[a]	Burning treatment	Age of understory	Average age of dominant pine	Average dbh of pine	Pines per acre	Basal area: Total trees	Basal area: Pine only	Site index[b]	Soil type and percent slope
		Years	Years	Inches	Number	Square feet		Feet	
5	Annual (10 burns)	1	31	9	180	92	92	95	Stough silt loam (0 - 2)
2	Annual (9 burns)	2	42	16	55	82	82	113	Stough v.f. sandy loam (0 - 1)
7	Annual (6 burns)	1	41	11	110	82	80	92	Providence silt loam (0 - <2)
1	Periodic (5 burns)	1	44	15	68	91	91	110	Calhoun silt loam (0 - 1)
4	Periodic (4 burns)	3	32	11	114	99	97	103	Leaf silt loam (0 - <2)
10	Periodic (4 burns)	3	43	17	53	102	88	106	Olivier silt loam (0 - <2)
6	Periodic (3 burns)	1	50	16	67	96	91	93	Providence silt loam (0 - 3)
3	Unburned	26	26	8	270	91	81	97	Stough v.f. sandy loam (0 - 1)
8	Unburned	43	43	13	63	109	68	87	Olivier silt loam (0 - <2)
9	Unburned	52	52	16	97	158	139	105	Springfield silt loam (0 - 1)

[a]Stands are numbered in the order of sampling in the field.

[b]Site index is for loblolly pine.

Figure 8. Stand burned annually.

Table 3. Trees and shrubs of the understory and midstory in stand 5 (somewhat poorly drained terrace soils with fragipans)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	------- Stems per Acre- --------				
loblolly pine	1200	0	0	0	1200
shining sumac	600	0	0	0	600
persimmon	600	0	0	0	600
willow oak	300	0	0	0	300
southern bayberry	300	0	0	0	300
blackgum	200	0	0	0	200
sparkleberry	200	0	0	0	200
live oak	200	0	0	0	200
Vaccinium sp.	100	0	0	0	100
southern red oak	100	0	0	0	100
Totals	3800	0	0	0	3800
Totals less pine	2600	0	0	0	2600

Table 4. Vines and herbaceous vegetation in stand 5 (somewhat poorly drained terrace soils with fragipans)

Species	Frequency Total of 50 subplots	Species	Frequency Total of 50 subplots
Panicum sp.	50	meadow beauty	4
elephant's foot	36	sheep-sorrel	4
Rubus sp.	30	cat greenbrier	3
buttonweed	30	partridge pea	3
beggar lice	25	pencil flower	2
Hypericum sp.	22	beakrush	1
Paspalum sp.	21	rabbit tobacco	1
waxweed	18	common greenbrier	1
violet	12	lespedeza	1
Eupatorium sp.	10	mint	1
Aster sp.	7	common ragweed	1
tephrosia	6	rattan vine	1
St. Andrew's cross	5	rattlebox	1
bugleweed	4	three awn	1
dichondra	4	trumpet vine	1
goldenrod	4		

loblolly pine. Shining sumac and persimmon accounted for an additional 32 percent of the stems in the understory. A total of 31 herb and vine species were counted, several of which occurred infrequently. Examination of the data reveals that eight herbaceous species occurred rather infrequently.

Stand 2. -- This stand is a natural stand of pure loblolly pine which occupies an area of about 20 acres owned by Crown Zellerbach Corporation. The stand is located in Livingston Parish, specifically the NW¼ SW¼ Sec. 25, T 5 S, R 4 E. The average age of the stand was 42 years. Soils are of drainage class 2. A rather complete history of cultural operations in this stand was available. In 1947, at age 20, a light pulpwood thinning was made and hurricane-damaged trees were removed. A low thinning for pulpwood was completed in 1951. Hardwood sawtimber removal and an improvement cutting for pulpwood were accomplished in 1955. A cutting for poles and piling and some pulpwood was made in 1962. In 1965 a few storm-damaged trees were removed. An improvement cutting in 1967 was the last cutting operation prior to the period of this study. This stand has been burned annually since 1960 for a total of nine prescribed burns. The forester in charge stated that the fire intensity of the burns in this stand was relatively low due to its small size and the care used in burning near an equipment shed.

Study of the data in Table 5 shows that 15 shrub and tree species were present in the understory. This stand had the largest number of stems in the understory of any stand studied due to the

Table 5. Trees and shrubs of the understory and midstory in stand 2 (somewhat poorly drained terrace soils with fragipans)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	- - - - - -	Stems per Acre	- - - - - -	- - - -	- - - -
loblolly pine	83,900	0	0	0	83,900
American beauty-berry	14,600	1,200	0	0	15,800
southern bayberry	9,900	0	0	0	9,900
water oak	800	0	0	0	800
American holly	700	0	0	0	700
American hornbeam	500	0	0	0	500
willow oak	400	0	0	0	400
blackgum	400	0	0	0	400
southern red oak	300	0	0	0	300
red maple	200	0	0	0	200
persimmon	200	0	0	0	200
yaupon	100	0	0	0	100
crabapple	100	0	0	0	100
parsley hawthorn	100	0	0	0	100
sweetgum	100	0	0	0	100
Totals	112,300	1,200	0	0	113,500
Totals less pine	28,400	1,200	0	0	29,600

occurrence of large numbers of one-year-old loblolly pine. The very large number of well distributed one-year-old loblolly pine seedlings indicates the ability of this species to become established on a forest floor devoid of heavy accumulations of organic debris (Figure 9). The exclusion of pine seedlings from the data indicate that American beautyberry contributed more than half of the woody stems in this stand. A large representation of herb and vine species are shown in Table 6.

Stand 7. -- This site included approximately 160 acres. It is a natural stand of loblolly pine with a few shortleaf pine scattered throughout. The average age of the stand was 41 years. Soils are of drainage class 3. Crown Zellerbach Corporation owns this stand which is located in St. Helena Parish. The part sampled was the W½ SE¼ Sec. 17, T 1 S, R 5 E. Verified information on cultural treatments other than prescribed burns was limited. It was assumed that the "normal" 5-year cutting cycles had been followed. A pulpwood thinning was carried out in 1966 by the present forester in charge. During the period 1964-1969, this stand was burned annually. Past history of fire prior to the recent management was not known. A few hardwoods were evident in the overstory; therefore, fire was probably excluded or occurred infrequently during the early life of the stand. The understory comprised 17 shrub and tree species and 33 herb and vine species (Tables 7 and 8). Of the woody stems present in the understory approximately 25 percent were sweetgum and 25 percent were loblolly and shortleaf pine.

Figure 9. One-year-old loblolly pine seedlings on an annually burned forest floor.

Table 6. Vines and herbaceous vegetation in stand 2 (somewhat poorly drained terrace soils with fragipans)

Species	Frequency Total of 50 subplots	Species	Frequency Total of 50 subplots
Panicum sp.	47	common greenbrier	7
waxweed	45	*Cyperus* sp.	5
partridge berry	33	leaf flower	5
Rubus sp.	32	pepper vine	5
dichondra	30	yankee weed	4
cross vine	25	rush	3
elephant's foot	18	poison ivy	3
buttonweed	14	Virginia creeper	3
sheep-sorrel	14	*Aster* sp.	2
yellow jessamine	14	*Carex* sp.	2
bur cucumber	13	cat greenbrier	2
beggar lice	12	mint	2
nightshade	11	grape	1
partridge pea	11	marsh fleabane	1
Eupatorium sp.	9	milkpea	1
rattan vine	9	evening primrose	1
common ragweed	8	three-seeded mercury	1

Table 7. Trees and shrubs of the understory and midstory in stand 7 (moderately well-drained loessal hills soil)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	-------	-Stems per Acre-	-------		
sweetgum	7,200	1,000	0	7	8,207
loblolly and shortleaf pine	8,100	0	0	13	8,113
flowering dog-wood	2,500	600	0	7	3,107
shining sumac	2,600	300	0	0	2,900
black cherry	1,500	100	0	0	1,600
water oak	1,400	0	0	0	1,400
blackgum	1,300	100	0	3	1,403
American beautyberry	300	700	0	0	1,000
Vaccinium sp.	700	0	0	0	700
blackjack oak	600	0	0	0	600
southern red oak	400	0	0	0	400
post oak	300	0	0	0	300
red mulberry	100	200	0	0	300
sassafras	200	0	0	0	200
red maple	200	0	0	0	200
winged elm	100	0	0	0	100
smooth sumac	100	0	0	0	100
Totals	27,600	3,000	0	30	30,630
Totals less pine	19,500	3,000	0	17	22,517

Table 8. Vines and herbaceous vegetation in stand 7 (moderately well-drained loessal hills soil)

Species	Frequency Total of 50 subplots	Species	Frequency Total of 50 subplots
yellow jessamine	49	dichondra	5
beggar lice	47	poison oak	4
Panicum sp.	47	Virginia creeper	4
Rubus sp.	39	cat greenbrier	3
elephant's foot	32	partridge berry	3
Hypericum sp.	28	sheep-sorrel	3
bedstraw	26	black snakeroot	2
partridge pea	26	goldenrod	2
Eupatorium sp.	25	poorjoe	2
red top	22	violet	2
milkpea	16	agrimony	1
poison ivy	11	*Carex* sp.	1
grape	8	clematis	1
common greenbrier	8	mint	1
rattan vine	8	*Paspalum* sp.	1
thistle	6	St. Andrew's cross	1
southern bracken	5		

Summary of stands burned annually. -- The annually burned stands have some obvious characteristics in common. One-year-old pine seedlings generally dominate in number of stems in the understory. The height of the understory is essentially less than 3 feet. Stand 7 was an exception in that about 10 percent of the total stems exceeded 3 feet. This condition is explained by the smaller number of annual burns made in stand 7. A relatively small number of shrub and tree species comprised the major part of the understory stratum, but a large representation of vine and herbaceous species is common.

Stands Burned Periodically

Four stands, numbers 1, 4, 10 and 6, were burned periodically (Figure 10). There was some variation in burning intervals as noted in the following discussion. Stand 4 and stand 10 were last burned in 1967.

Stand 1. -- Stand 1 is an area of about 440 acres and is a natural stand of loblolly pine which contains an occasional spruce pine (Pinus glabra Walt.). The stand is located in Livingston Parish and is owned by Crown Zellerbach Corporation. The specific site studied is the SE¼ SW¼ Sec 36, T 5 S, R 4 E. Average age of the stand was 44 years. Soil type is of drainage class 1. There were no hardwoods in the overstory of the sampled segment due to the cutting operations and prescribed burning. Low thinnings for pulpwood and for stand improvement have been the policy followed in this stand. The emphasis has been on overtopped and intermediate class trees although codominants

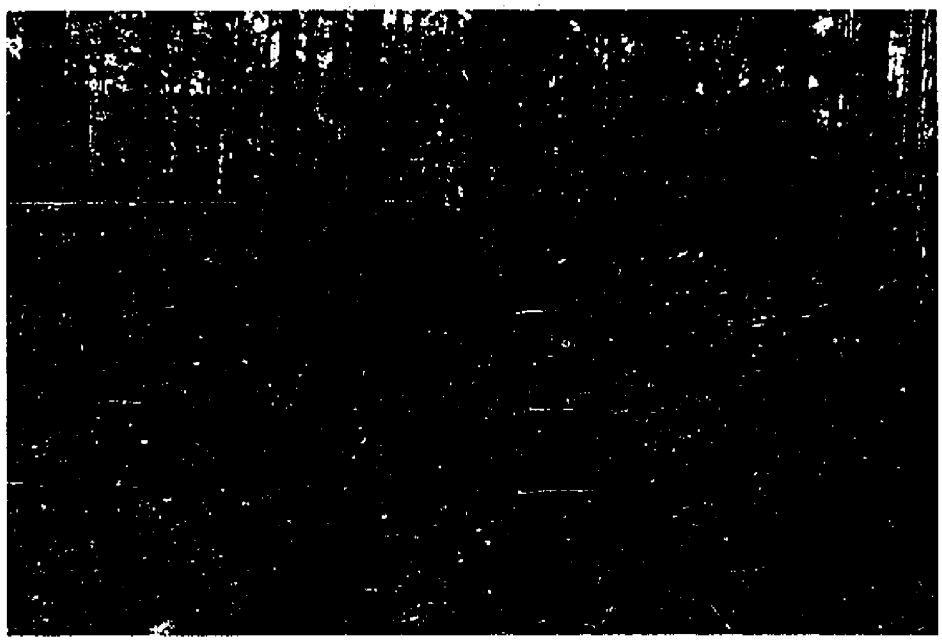


Figure 10. Stand burned periodically.

were occasionally marked for cutting. Selective pulpwood thinnings, in which marked trees were harvested, were made in 1952 and 1955. In 1954 a selective hardwood cut was carried out along with the removal of cull hardwood. The last cutting operation prior to the time of this study was for poles and piling and for stand improvement in 1965. This stand was prescribed burned in 1959, 1962, 1965, 1968, and 1969. The fire in 1969 was intense at several spots but did no apparent damage to the overstory pine. This last fire was in preparation for the harvest cut.

Loblolly pine seedlings accounted for 6 percent of the total stems in stand 1. American beautyberry contributed 39 percent of the total stems and 42 percent of all hardwood stems. Five species, American beautyberry, persimmon, sweetgum, blackgum, and southern bayberry, comprised 87 percent of the total stems. There were 14 shrub and tree species represented but eight of these occurred infrequently (Table 9). Only four vine and herbaceous species out of a total of 35 had wide distribution (Table 10). Waxweed, Panicum sp., and Rubus sp. were especially plentiful.

Stand 4. -- This tract of approximately 80 acres of loblolly pine is in the 25- to 35-year class. Soils are of drainage class 1. The stand is located in Livingston Parish, the SE¼ Sec 34, T 5 S, R 6 E. This stand had not received intensive management because of its isolation from other International Paper Company lands. Some scattered hardwoods over 4 inches dbh were noticeable. A greater variation in the dbh of pine was noted in this stand than in any other burned stand in the

Table 9. Trees and shrubs of the understory and midstory in stand 1 (poorly drained flatwoods soil)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	- - - - - - - -	Stems per Acre	- - - - - - - -		
American beautyberry	10,400	0	0	0	10,400
persimmon	5,200	300	0	0	5,500
sweetgum	3,000	0	0	0	3,000
blackgum	2,200	0	0	0	2,200
southern bay-berry	1,800	0	0	0	1,800
loblolly pine	1,500	0	0	0	1,500
red maple	500	0	0	0	500
parsley haw-thorn	400	0	0	0	400
yaupon	300	0	0	0	300
cherrybark oak	100	100	0	0	200
post oak	200	0	0	0	200
water oak	200	0	0	0	200
willow oak	100	0	0	0	100
palmetto	0	100	0	0	100
Totals	25,900	500	0	0	26,400
Totals less pine	24,400	500	0	0	24,900

Table 10. Vines and herbaceous vegetation in stand 1 (poorly drained flatwoods soil)

Species	Frequency Total of 50 subplots	Species	Frequency Total of 50 subplots
waxweed	49	poison ivy	4
Panicum sp.	48	cat greenbrier	3
Rubus sp.	35	bur cucumber	2
grape	22	elephant's foot	2
Eupatorium sp.	12	*Hypericum* sp.	2
Paspalum sp.	9	common ragweed	2
Carex sp.	8	rattan vine	2
Cyperus sp.	8	trumpet vine	2
beggar lice	7	Virginia creeper	2
cross vine	7	lanceleaf greenbrier	1
partridge berry	7	hydrangea	1
sheep-sorrel	7	Japanese climbing fern	1
buttonweed	6	pepper vine	1
water primrose	6	rattlebox	1
mint	6	ruellia	1
dandelion	5	smartweed	1
nightshade	5	violet	1
common greenbrier	4		

study. A forestry technician who had worked in the area for 20 years could not remember any cutting operation in the stand. He had prescribed burned the area four times on an average of every three years. The last burn in 1967 most likely was spotty since patches of pine regeneration over 8 feet tall were observed. A relatively large number of understory plant species were recorded. Loblolly pine seedlings accounted for 44 percent of the stems. Five species, southern bayberry, sumac, sweetgum, sparkleberry and American beautyberry, totaled 73 percent of stems excluding pine (Table 11). About 9 percent of the understory stems exceeded 3 feet in height. A large number (48) of vine and herbaceous species were recorded, but 18 occurred infrequently (Table 12). *Panicum* sp. and *Rubus* sp. were widely distributed and beggar lice was also common.

Stand 10. -- This stand is located in Livingston Parish and includes about 560 acres of loblolly pine with an average age of 43 years. The sampled area is the NW¼ SW¼ Sec 10, T 5 S, R 4 E. The soil is of drainage class 2. Owner of the stand is Crown Zellerbach Corporation. The first cutting of record in the stand was in 1957, when a pine and hardwood sawtimber cut was made with pulpwood removal as part of the operation. A similar operation with emphasis on stand improvement was carried out in 1962. The last cutting operation was for poles and piling in 1967. Prescribed burns were made in 1956, 1960, 1965 and 1967. The 1967 burn started as a wildfire and company personnel turned it into a controlled burn on all of the tract. This stand, like stand 4, had three seasons of understory growth at the time of sampling.

Table 11. Trees and shrubs of the understory and midstory in stand 4 (poorly drained flatwoods soil)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	- - - - - - - -	Stems per Acre	- - - - - - - -		
loblolly pine	10,100	200	0	0	10,300
southern bayberry	3,300	300	100	0	3,700
shining sumac	1,900	200	0	0	2,100
sweetgum	1,600	100	0	0	1,700
sparkleberry	1,000	100	0	0	1,100
American beauty-berry	1,000	0	0	0	1,000
post oak	800	100	0	0	900
persimmon	600	100	0	0	700
Vaccinium sp.	700	0	0	0	700
blackgum	300	100	0	0	400
red maple	200	0	0	0	200
winged elm	100	100	0	0	100
black cherry	100	0	0	0	100
laurel oak	100	0	0	0	100
southern red oak	100	0	0	0	100
water oak	100	0	0	0	100
Totals	22,000	1,300	100	0	23,400
Total less pine	11,900	1,100	100	0	13,100

Table 12. Vines and herbaceous vegetation in stand 4 (poorly drained flatwoods soil)

Species	Frequency Total of 50 subplots	Species	Frequency Total of 50 subplots
Panicum sp.	42	dandelion	2
Rubus sp.	41	rabbit tobacco	2
beggar lice	25	common greenbrier	2
elephant's foot	23	St. Andrew's cross	2
Eupatorium sp.	19	black snakeroot	2
Hypericum sp.	18	three-seeded mercury	2
three awn	17	bur cucumber	1
Japanese climbing fern	15	butterfly pea	1
yellow jessamine	14	cat greenbrier	1
trumpet vine	10	marsh fleabane	1
partridge pea	9	mint	1
tephrosia	9	nightshade	1
goldenrod	8	partridge berry	1
Aster sp.	5	*Paspalum* sp.	1
cross vine	5	*Polypremum procumbens*	1
milkpea	5	water primrose	1
poison ivy	5	common ragweed	1
poorjoe	5	rose pink	1
dichondra	4	rushfoil	1
grape	4	ruellia	1
honeysuckle	4	sheep-sorrel	1
rattan vine	3	trilisia	1
sow thistle	3	Virginia creeper	1
Centella erecta	2	waxweed	1

The 19 shrub and tree species combined with 43 herb and vine species gave the highest total number of plant species found in any stand (Tables 13 and 14). Loblolly pine seedlings were well-distributed in large numbers and contributed 65 percent of the total stems. American beautyberry, southern bayberry, sweetgum, and blackgum made up 61 percent of all hardwood stems. More than 19 percent of all hardwood stems exceeded 3 feet in height. Some hardwoods were present in the overstory. The understory was characterized by dense thickets of briars, vines, and shrubs. Only _Rubus_ sp., _Panicum_ sp. and grape had high frequencies of occurrence (Table 14).

Stand 6. -- This area of approximately 100 acres, was a natural stand of loblolly pine with scattered shortleaf pine located in St. Helena Parish. The average of the stand was 50 years. Crown Zellerbach Corporation is the owner of this stand, which is situated on soils of drainage class 3. Sampling was completed within the northwestern part of Sec. 70, T 1 S, R 4 E. Cultural treatments included an improvement thinning for pulpwood made in 1958. A pole-and-piling cut and a thinning for pulpwood was completed in 1963. Prescribed burns were made in 1956, 1961, and 1969. The 8-year interval between the last two burns was the longest in any stand studied. Available information indicates that stand 6 had not been burned prior to 1956. Scrutiny of Tables 15 and 16 shows a total of 19 shrub and tree species and 42 herb and vine species represented in the understory. The number of species was equaled in other stands, but the total number of hardwood stems recorded in stand 6 far exceeded that found elsewhere in the

Table 13. Trees and shrubs of the understory and midstory in stand 10 (somewhat poorly drained terrace soils with fragipans)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	- - - - - - - - -	-Stems per Acre	- - - - - - - - -		
loblolly pine	43,800	0	0	0	43,800
American beauty-berry	3,100	2,200	0	0	5,300
southern bayberry	3,700	300	0	7	4,007
sweetgum	2,200	900	0	10	3,110
blackgum	2,000	400	0	3	2,403
yaupon	1,600	0	0	0	1,600
American hornbeam	1,400	0	0	0	1,400
sweetleaf	900	200	0	0	1,100
shining sumac	700	200	100	27	1,027
red maple	1,000	0	0	0	1,000
persimmon	400	200	0	33	633
winged elm	600	0	0	0	600
parsley hawthorn	600	0	0	0	600
southern red oak	300	0	0	3	303
cherrybark oak	300	0	0	0	300
pignut hickory	200	0	0	0	200
water oak	200	0	0	0	200
red mulberry	200	0	0	0	200
willow oak	100	0	0	0	100
Totals	63,200	4,500	100	83	67,883
Totals less pine	19,400	4,500	100	83	24,083

Table 14. Vines and herbaceous vegetation in stand 10 (somewhat poorly drained terrace soils with fragipans)

Species	Frequency Total of 50 subplots	Species	Frequency Total of 50 subplots
Rubus sp.	45	Virginia creeper	4
Panicum sp.	44	flowering spurge	3
grape	29	grapefern	3
elephant's foot	17	black snakeroot	3
goldenrod	16	clematis	2
St. Andrew's cross	16	cat greenbrier	2
beggar lice	15	dwarf greenbrier	2
Eupatorium sp.	14	lanceleaf greenbrier	2
dichondra	13	*Ludwigia* sp.	2
Hypericum sp.	12	nightshade	2
yellow jessamine	12	blue wild indigo	2
cross vine	11	*Aster* sp.	1
poison ivy	10	buttonweed	1
partridge pea	9	*Carex* sp.	1
common greenbrier	7	meadow beauty	1
Japanese climbing fern	7	*Paspalum* sp.	1
bedstraw	6	common ragweed	1
partridge berry	6	red top	1
violet	6	sheep-sorrel	1
bur cucumber	5	three-seeded mercury	1
Hyptis alata	5	waxweed	1
rattan vine	4		

Table 15. Trees and shrubs of the understory and midstory in stand 6 (moderately well-drained loessal hils soil)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	- - - - - - - -	-Stems per Acre	- - - - - - - -		
southern bayberry	22,100	0	0	0	22,100
yaupon	5,900	400	0	0	6,300
flowering dogwood	5,300	600	0	23	5,923
sweetgum	4,200	400	0	10	4,610
red maple	3,800	300	0	0	4,100
Vaccinium sp.	3,600	0	0	0	3,600
blackgum	2,600	200	0	0	2,800
loblolly and short-leaf pine	2,700	0	0	3	2,703
water oak	2,400	200	0	0	2,603
American beauty-berry	1,200	1,400	0	0	2,600
sparkleberry	1,500	200	0	0	1,700
shining sumac	1,200	400	0	0	1,600
black cherry	1,500	0	0	0	1,500
southern red oak	1,200	100	0	0	1,300
American holly	1,000	100	0	0	1,100
sassafras	500	0	0	0	500
blackjack oak	400	0	0	0	400
smooth sumac	200	0	0	0	200
persimmon	100	0	0	0	100
Totals	61,400	4,300	0	39	65,739
Totals less pine	58,700	4,300	0	36	63,036

Table 16. Vines and herbaceous vegetation in stand 6 (moderately well-drained loessal hills soil)

Species	Frequency Total of 50 subplots	Species	Frequency Total of 50 subplots
Panicum sp.	44	sheep-sorrel	4
beggar lice	41	saw greenbrier	4
yellow jessamine	38	dichondra	3
partridge pea	35	milkpea	3
Rubus sp.	34	black snakeroot	2
Eupatorium sp.	31	dropseed	2
elephant's foot	29	Macartney rose	2
Virginia creeper	28	mint	2
partridge berry	27	tephrosia	2
grape	23	bur cucumber	1
poison ivy	20	cross vine	1
Hypericum sp.	17	choisy	1
goldenrod	14	dog fennel	1
bedstraw	11	dwarf greenbrier	1
Andropogon sp.	10	flowering spurge	1
thistle	10	horsemint	1
cat greenbrier	9	Japanese climbing fern	1
rattan vine	7	*Paspalum* sp.	1
Carex sp.	6	rattlebox	1
common greenbrier	6	sow thistle	1
poorjoe	5	trumpet vine	1

study. Pine seedlings represented only 4 percent of total stems in the understory. Southern bayberry accounted for 34 percent of total stems. Several shrub and tree species were well distributed among the stem totals (Table 15). Study of the data shows that nearly 7 percent of all hardwood stems exceeded 3 feet in height after one growing season. At least 11 vine and herbaceous species had relatively large frequency percentages. Examination of the data in Table 16 shows that Panicum sp., beggar lice, yellow jessamine, partridge pea, Rubus sp., and Eupatorium sp. had frequency percentages of 60 or larger.

Summary of stands burned periodically. -- The periodically burned stands (1, 4, 10, and 6) have both similarities and differences. Stand 1 was burned in 1968 and 1969, and the last burn was rather intense. This stand has many characteristics in common with the stands burned annually. The other stands burned periodically show parallel trends in the subsequent development of understory vegetation. The understory showed much more variation in height growth than in the stands burned annually. There is a large number of shrub and tree species in these stands, which accounts for a substantial percentage of the total stems. Vine and herbaceous species do not differ much in number from stands burned annually; however, there is a difference in numbers of frequently occurring species.

Stands Unburned

Stands 3, 8, and 9 had never been burned according to landowners and/or individuals familiar with the area. Field observation by the author supported this fact (Figure 11).

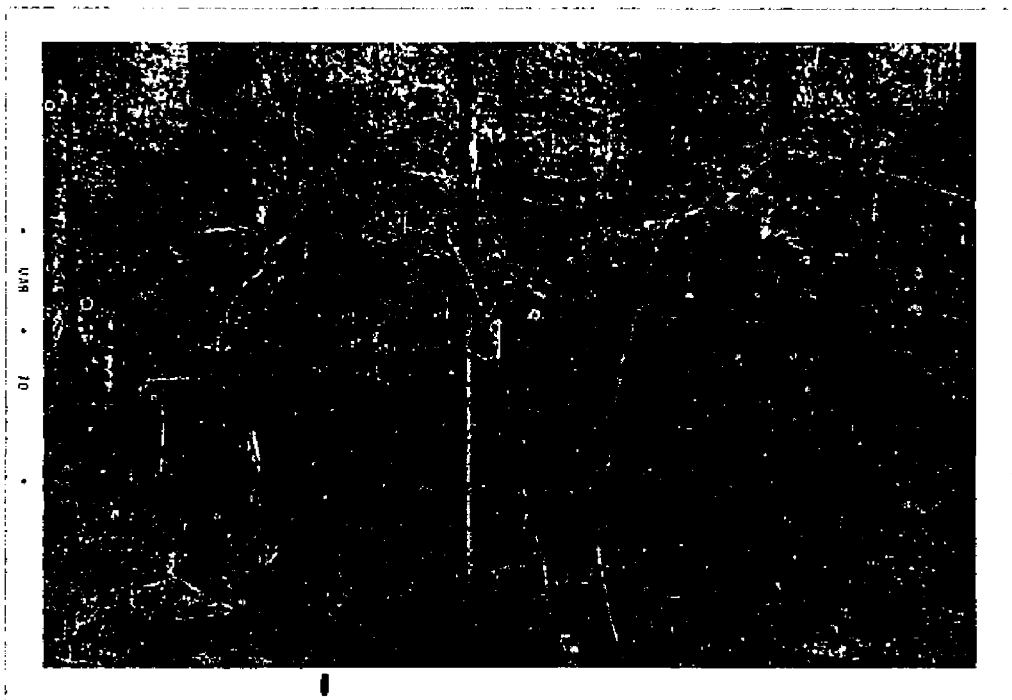


Figure 11. A typical unburned stand.

Stand 3. -- This stand comprised about 30 acres of young loblolly pine-hardwood timber (average stand age of 26 years) which had developed on an old cultivated field. It is located in the NE corner of Sec 37, T 5 S, R 6 E, Livingston Parish. An absentee owner holds the deed to the property. The stand is situated on soil of drainage class 2. The stand showed no evidence of management. Approximately 3 inches of leaf litter covered the forest floor. This accumulation apparently limited the distribution of herbaceous vegetation. Study of Tables 17 and 18 reveals a larger number of shrub and tree species than herb and vine species. Pine seedlings were few in number due to the competition of hardwoods and the litter accumulation on the forest floor. Southern bayberry, laurel oak, and sweetgum accounted for 55 percent of the total stems: Several shrub and tree species were represented in both the understory and the midstory. There was a blending of hardwood understory species with the overstory of pine and hardwood. Only *Panicum* sp. and yellow jessamine of the herb and vine species had fairly wide distribution.

Stand 8. -- This site was a 200-acre tract owned by a local church. The area chosen for study included pine in the 40- to 50-year age class similar to that found on the burned stands studied in the loessal hills. Loblolly pine was dominant, but shortleaf pine contributed about 35 percent of the pine sampled. This stand is located in St. Helena Parish in the south-central part of Sec. 76, T 1 S, R 4 E. Soils are of drainage class 2. According to a resident forest technician, selective pine thinnings were made in 1944 and in 1958.

Table 17. Trees and shrubs of the understory and midstory in stand 3 (somewhat poorly drained terrace soils with fragipans)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	- - - - - - - -	-Stems per Acre-	- - - - - - - -		
southern bayberry	2,100	200	0	70	2,370
laurel oak	1,100	100	300	0	1,500
sweetgum	900	300	200	93	1,493
blackjack oak	700	0	0	3	703
blackgum	400	0	200	73	673
sparkleberry	100	400	0	30	530
willow oak	300	0	0	3	303
southern red oak	200	0	0	33	233
loblolly pine	200	0	0	13	213
American holly	200	0	0	3	203
shining sumac	200	0	0	3	203
persimmon	200	0	0	0	200
arrowwood	200	0	0	0	200
sweetbay	200	0	0	0	200
water oak	200	0	0	0	200
crabapple	100	0	0	10	110
possumhaw	100	0	0	0	100
red chokeberry	100	0	0	0	100
dogwood	0	0	0	84	84
post oak	0	0	0	7	7
Totals	7,400	1,000	800	425	9,625
Totals less pine	7,200	1,000	800	412	9,412

Table 18. Vines and herbaceous vegetation in stand 3 (somewhat poorly drained terrace soils with fragipans)

Species	Frequency Total of 50 subplots	Species	Frequency Total of 50 subplots
Panicum sp.	24	cat greenbrier	4
yellow jessamine	22	elephant's foot	3
Rubus sp.	14	*Eupatorium* sp.	3
common greenbrier	11	mint	2
poison ivy	8	rattan vine	2
beggar lice	6	grape	1
Carex sp.	6	*Hypericum* sp.	1
partridge berry	5	Virginia creeper	1

Otherwise, no management had been practiced. Analysis of the data in Tables 19 and 20 suggests the nature of the stand. It is characterized by a dense hardwood understory and midstory (19 shrub and tree species were tallied) and by large hardwood species such as oaks and sweetgum in the overstory. Except for the surface of an old access road, the forest floor was almost clear of herbaceous growth due to the lack of light and the heavy accumulation of organic litter (Figure 12). A total of 23 herb and vine species were found, but only three of these, partridge berry, yellow jessamine, and Panicum sp., occurred with any regularity (Table 20).

Stand 9. -- Stand 9 is a natural stand of loblolly pine-hardwood which covers about 30 acres. The average stand age was 52 years. It is located in Tangipahoa Parish in the S½ SE¼ Sec 58, T 7 S, R 7 E. Soil type is of drainage class 1. This stand is privately owned by an absentee owner. Inquiry of long-term residents revealed no burning or management had been applied. Study of the data in Tables 21 and 22 supports this position. Twenty shrub and tree species were recorded along with 17 herb and vine species. Red maple, sparkleverry, sweetgum, and willow oak comprised 56 percent of the total stems, but several hardwood species were represented throughout the stand. As in stand 8, a very small number of herb and vine species occurred with any regularity. Partridge berry, Panicum sp., poison ivy, and common greenbrier were the most common species. A heavy fuel accumulation of about 4 inches formed a map over the forest floor (Figure 13). The exceptionally fine loblolly pine of the overstory was interspersed with large hardwoods and an occasional spruce pine.

Table 19. Trees and shrubs of the understory and midstory in stand 8 (somewhat poorly drained terrace soils with fragipans)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	- - - - - - - -	Stems per Acre	- - - - - - - -		
red maple	3,700	300	0	30	4,030
dogwood	2,500	200	0	137	2,837
sparkleberry	2,300	100	100	23	2,523
arrowwood	2,200	100	0	7	2,307
Vaccinium sp.	2,200	100	0	0	2,300
blackgum	1,500	0	0	13	1,513
loblolly pine	1,400	0	0	3	1,403
southern bayberry	1,100	0	0	0	1,100
sweetgum	600	200	100	94	994
parsley hawthorn	800	100	0	30	930
water oak	700	100	0	27	827
Crataegus sp.	500	0	0	0	500
American beauty-berry	400	0	0	0	400
wild azalea	400	0	0	0	400
strawberry bush	200	200	0	0	400
sweetleaf	100	200	0	3	303
southern magnolia	200	0	0	0	200
possumhaw	100	0	0	33	133
post oak	100	0	0	20	120
yaupon	0	0	0	84	84
southern red oak	0	0	0	20	20
sourwood	0	0	0	20	20
American holly	0	0	0	10	10
American elm	0	0	0	7	7
snowbell	0	0	0	7	7
sassafras	0	0	0	3	3
Totals	21,000	1,600	200	571	23,371
totals less pine	19,600	1,600	200	568	21,968

Table 20. Vines and herbaceous vegetation in stand 8 (somewhat poorly drained terrace soils with fragipans)

Species	Frequency Total of 50 subplots
partridge berry	40
yellow jessamine	30
Panicum sp.	21
common greenbrier	13
poison ivy	9
Rubus sp.	8
grape	7
goldenrod	4
dwarf greenbrier	4
beggar lice	3
elephant's foot	3
rattan vine	3
bedstraw	2
flowering spurge	2
honeysuckle	2
ruellia	2
cross vine	1
Eupatorium sp.	1
dichondra	1
cat greenbrier	1
Hypericum sp.	1
St. Andrew's cross	1
violet	1

Figure 12. Surface litter of pine and hardwood leaves in an unburned stand.

Table 21. Trees and shrubs of the understory and midstory in stand 9 (poorly drained flatwoods soils)

Species	Less than 3 feet	3 to 6 feet	6 to 8 feet	Mid-story	Totals
	- - - - - - - - Stems per Acre - - - - - - - -				
red maple	4,300	0	0	77	4,377
sparkleberry	1,000	300	0	43	1,343
sweetgum	400	500	0	264	1,164
willow oak	1,000	0	0	40	1,040
cherrybark oak	500	100	100	234	934
American hornbeam	300	300	0	17	617
red chokeberry	600	0	0	0	600
Crataegus sp.	600	0	0	0	600
blackgum	400	100	0	73	573
black cherry	400	0	0	20	420
water oak	300	0	0	117	417
southern bayberry	300	100	0	3	403
persimmon	300	0	0	7	307
American beautyberry	300	0	0	0	300
white oak	0	100	100	40	240
arrowwood	200	0	0	17	217
deciduous holly	100	0	0	60	160
laurel oak	100	0	0	10	110
winged elm	0	0	0	110	110
red bay	100	0	0	0	100
white ash	0	0	0	63	63
southern red oak	0	0	0	20	20
sweetleaf	0	0	0	13	13
pignut hickory	0	0	0	10	10
yaupon	0	0	0	10	10
American holly	0	0	0	7	7
snowbell	0	0	0	7	7
southern magnolia	0	0	0	7	7
dogwood	0	0	0	3	3
post oak	0	0	0	3	3
Totals	11,200	1,500	200	1,275	14,175

Table 22. Vines and herbaceous vegetation in stand 9 (poorly drained flatwoods soils)

Species	Frequency Total of 50 subplots
partridge berry	43
Panicum sp.	28
poison ivy	25
common greenbrier	19
Rubus sp.	13
cross vine	11
grape	5
elephant's foot	3
cat greenbrier	3
Hypericum sp.	2
Virginia creeper	2
bedstraw	1
Eupatorium sp.	1
dwarf greenbrier	1
poison oak	1
yellow jessamine	1
violet	1

Figure 13. Heavy pine needle accumulation on unburned forest floor.

Summary of unburned stands. -- The three unburned stands have much in common even though stand 3 is considerably younger than stands 8 and 9. The multistory effect in the unburned stands was absent from the burned stands. A large number of shrub and tree species is represented in each of the unburned stands. A small number of hardwood species may be dominant in the number of total stems, but several species have substantial percentages of the total stems. Vine species were common in all stands in the study but were usually much larger in unburned stands. There were few herbaceous species in the unburned stands. Ordinarily, three or four had high frequency distributions, but the numbers were far fewer than in burned stands. There is little light reaching the forest floor and this factor along with litter accumulation greatly limits herbaceous growth.

Discussion of Results

Quantitative methods in ecology are supplemental to description and are never interpretations as such. Interpretation is a process in the ecologist's mind after he has studied the descriptive data, whether they be qualitative or quantitative (Goodall 1952). In the present study, statistical analysis is valuable in several respects but must be supplemented by field observation and interpretation of descriptive data.

Influence of Burning Treatments on Number of Stems in the Understory

Some tabulations were made and stem totals were averaged by burning treatments, by soil drainage classes, and by overstory cover classes. These data are presented in the following discussion.

Stands burned annually had a higher average stem total than stands burned periodically or unburned stands. Total stems in the understory is somewhat misleading, since one-year-old loblolly pine seedlings accounted for the larger portion of total stems in stands burned annually and for a relatively large number of stems in stands burned periodically (Figure 14). The number of pine seedlings is useful to show the regenerative potential of a forest free of thick litter accumulations and with a reduced hardwood understory. Annual burning keeps the forest floor in good condition for pine seed germination. A good seed crop will generally have favorable surface conditions on areas burned annually, but stands burned on a periodic basis might have a poor seed crop during the year when the prescribed burn is made.

Unless there are plans for regeneration of a stand, however, the number of pine seedlings is not silviculturally important. Also, any prescribed burn moving through such a stand will kill the pine seedlings. If a fire does not remove the seedlings, they usually die from competition as a result of low light conditions. Under a well-developed overstory, few southern pine seedlings survive long, because the available light that reaches the forest floor is generally insufficient to sustain photosynthesis beyond the compensation point, especially under dry conditions.

Kramer and Decker (1944) found that photosynthesis of loblolly pine increased with light intensity up to almost full sunlight. They concluded the lack of sufficient light for maximum photosynthesis might be a significant factor in failure of pine seedlings to become established under forest stands. There is also the hypothesis that the relatively low rate of photosynthesis of pine seedlings in the understory may be the result of mutual shading of the pine needles by one another. This effect is due to the arrangement of pine needles (Kramer and Clark 1947).

Pine was almost absent from unburned stands. The lack of available light was unquestionably important, but the heavy accumulations of forest litter formed barriers to seed germination.

Hardwood stem totals are very meaningful to the manager of pine forests in the South. Study of Figure 14 shows almost twice the number of hardwood stems on stands burned periodically compared to the stands burned annually. These data indicate that annual late winter or spring burning is effective in <u>killing</u> hardwoods as well as killing back and reducing the average height growth of the understory (Figure 15). No stems exceeded 6 feet in height on <u>annually burned stands</u>.

<u>Influence of Soil Drainage on the Number of Stems in the Understory</u>

The data on understory stems as influenced by soil drainage conditions are shown in Figure 16. A large difference in total stems

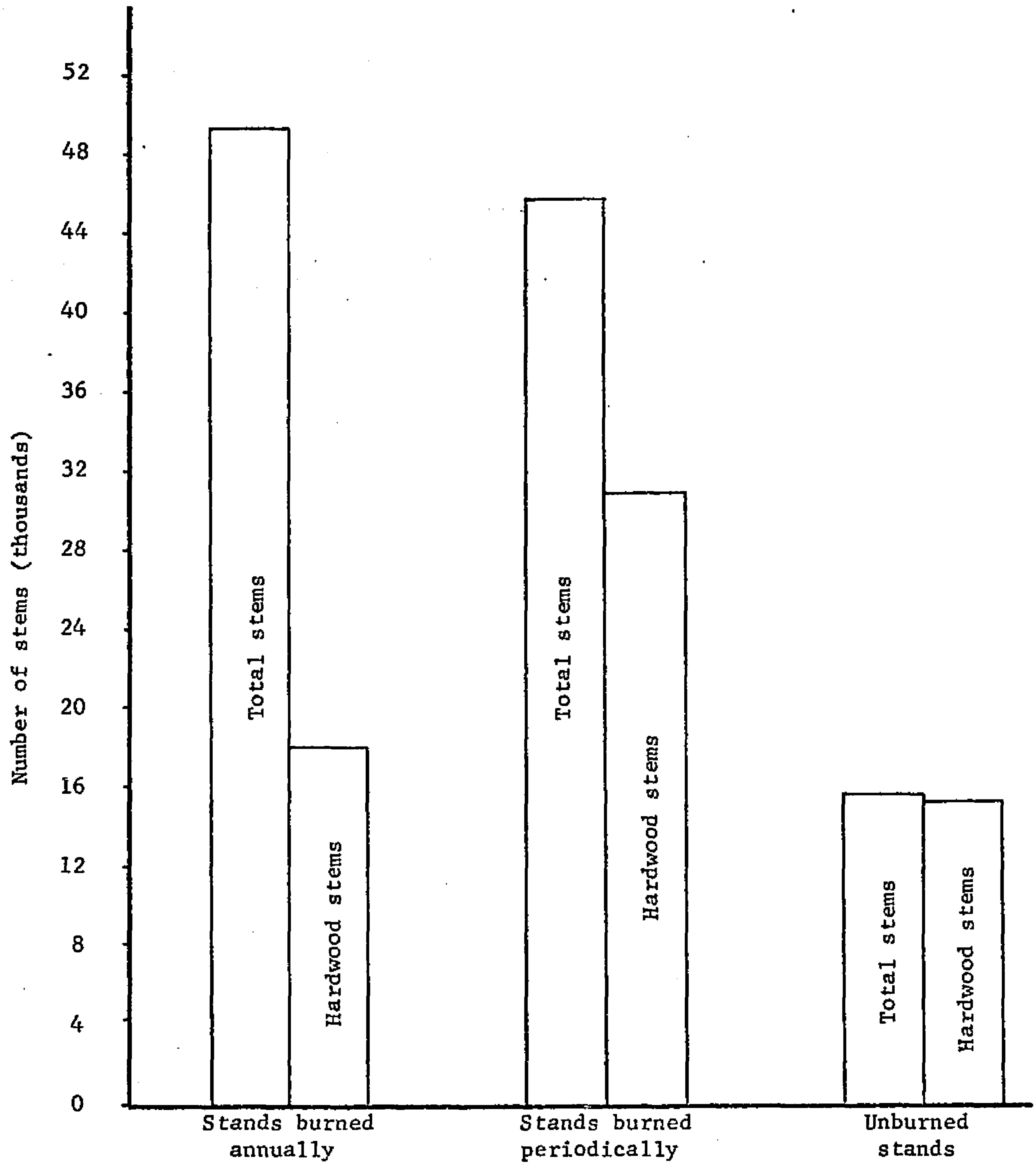


Figure 14. Average stem totals per acre on the basis of burning treatment.

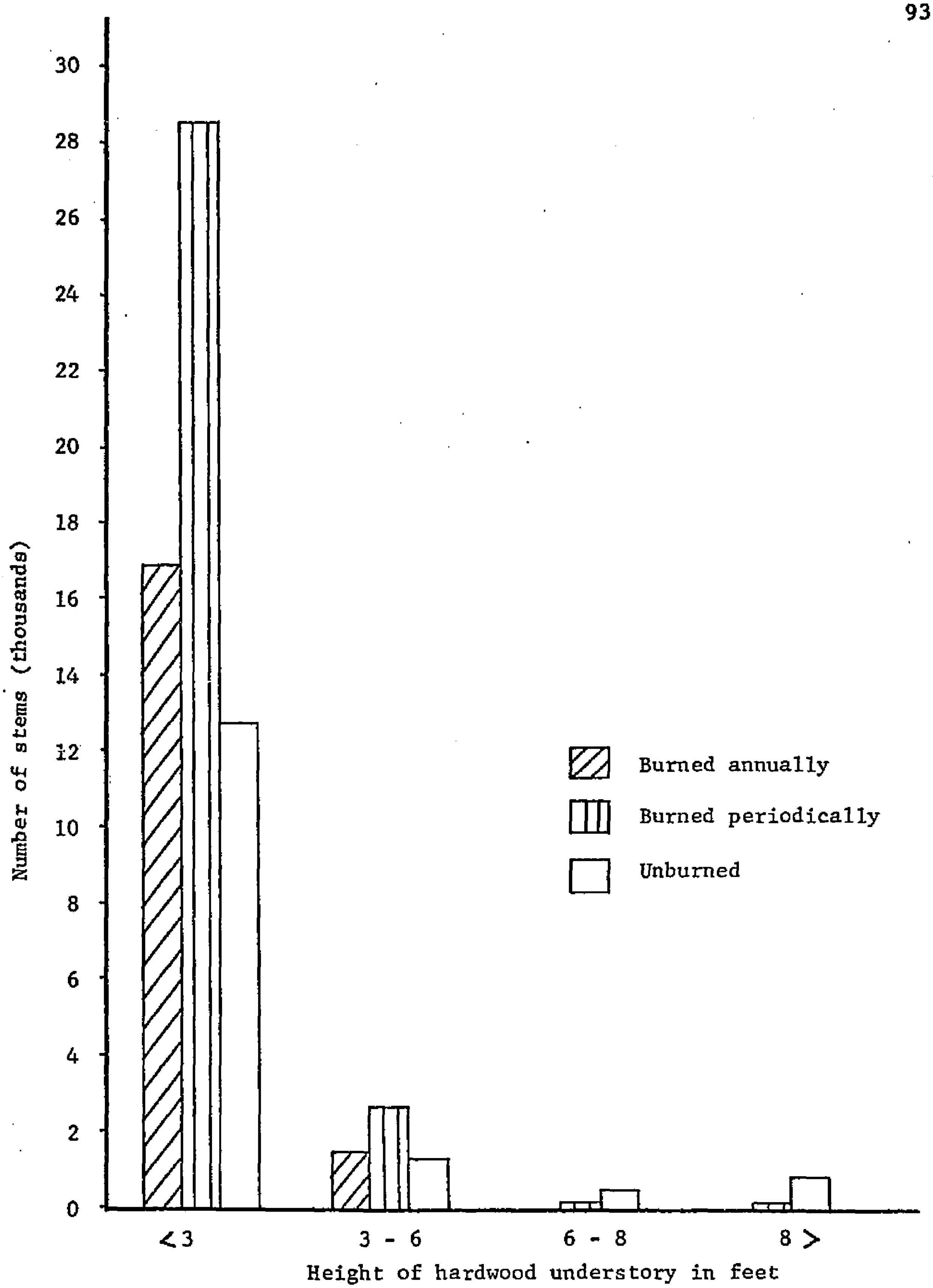


Figure 15. Hardwood stem totals per acre by burning treatment and height classes.

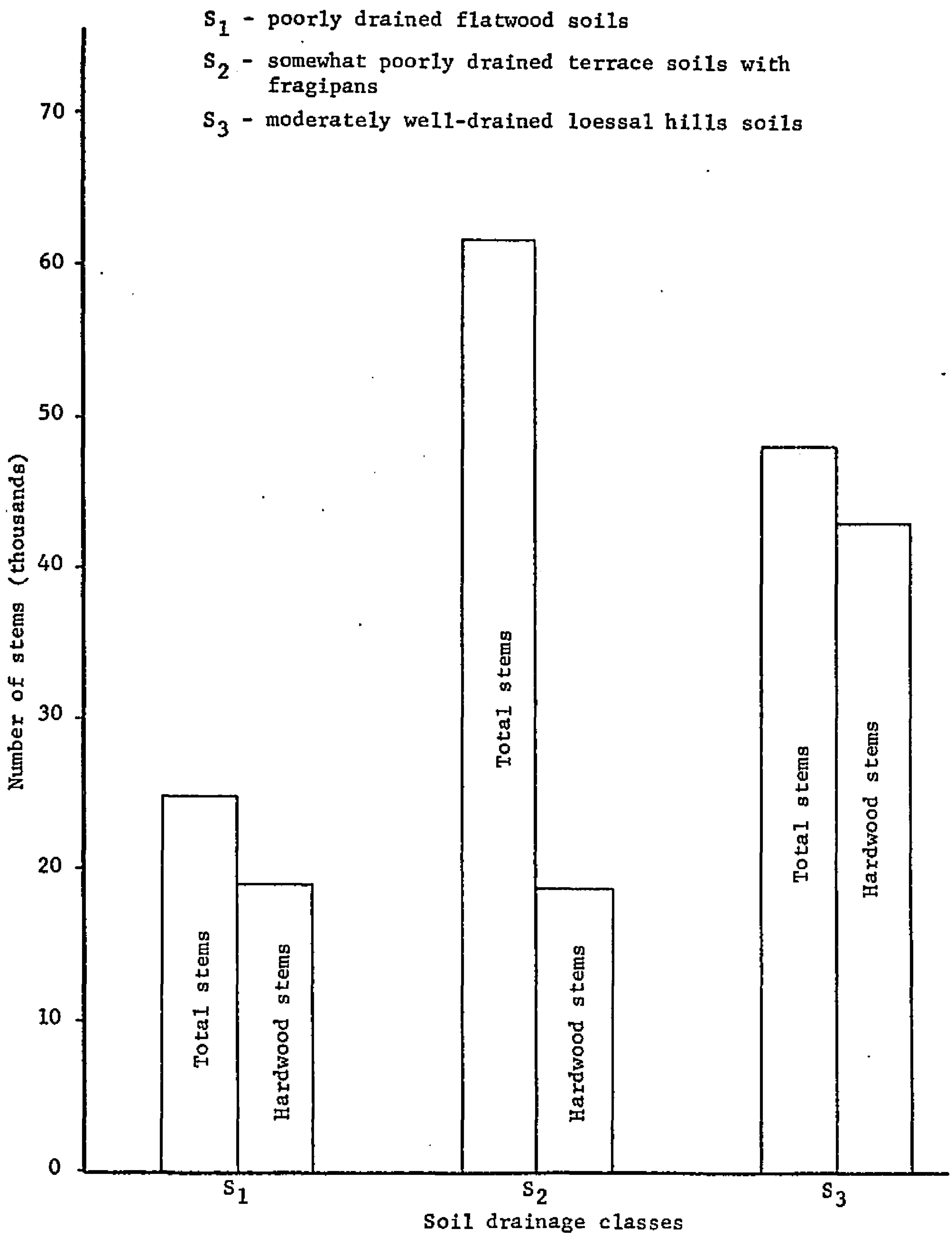


Figure 16. Stem totals per acre by soil drainage classes.

between poorly-drained flatwoods soils (S_1) and somewhat poorly drained terrace soils with fragipans (S_2) is most evident; however, the number of hardwood stems was essentially the same on these types of soil. The most significant observation is the number of hardwood stems on the moderately well-drained loessal hills soils (S_3). The average number of stems is more than twice that of the other two soil drainage classes. These data might indicate a better hardwood site for a larger number of species on the better drained soils.

Influence of the Overstory on the Development of Understory Vegetation

The extent of influence of the overstory on the development of an understory vegetation is controversial. Although there are many ecologists who support the Finnish system of forest classification, it appears to have few supporters in the eastern half of the United States. The Finnish system considers the pattern of undergrowth to be determined directly by intrinsic physical factors of the habitat rather than a reflection of differences in the nature of tree cover from place to place (Daubenmire and Daubenmire 1968). The Daubenmires concluded from research over a period of many years in the northern Rocky Mountains that forest overstory and understory occupy the ground independently. They found the same tree canopy existing over almost completely different ground flora. They also found similar undergrowth types existing under different overstory species.

Stanley (1938), working in New Hampshire, found that soil moisture was more important than light in regulating vegetation on the forest floor. He found no correlation between light intensity and degree of cover of the understory vegetation.

Rowe (1956) recognized that various environmental factors influence the overstory as well as the understory vegetation; however, he was convinced that light was the principal factor which controlled the structure of understory vegetation. The amount of light reaching the forest floor is affected by the amount of overstory cover and the higher of the overstory.

The growth and development of vegetation is affected in one way or another by temperature differences in the air and soil, by edaphic factors such as soil moisture and soil fertility, by slope (affects subsurface and surface drainage), aspect (affects temperature and light conditions), and by other geographic conditions such as the precipitation regime.

In the study area the degree of soil drainage was more important than the availability of soil moisture. Generally, with the moderately heavy precipitation characteristics of this area, soil moisture is in available supply during most of the growing season. Temperature is no limiting factor so far as growth is concerned in this area. It appears that the extent of the overstory canopy and its influence on available light is extremely important. Figure 17 is an illustration of the data from annually burned and periodically burned stands on the basis of overstory cover percentage. The stands had representation of annual and periodic burning and soil drainage classes. The only obvious variable was the density of the overstory cover. Stands 2, 1, and 6 were

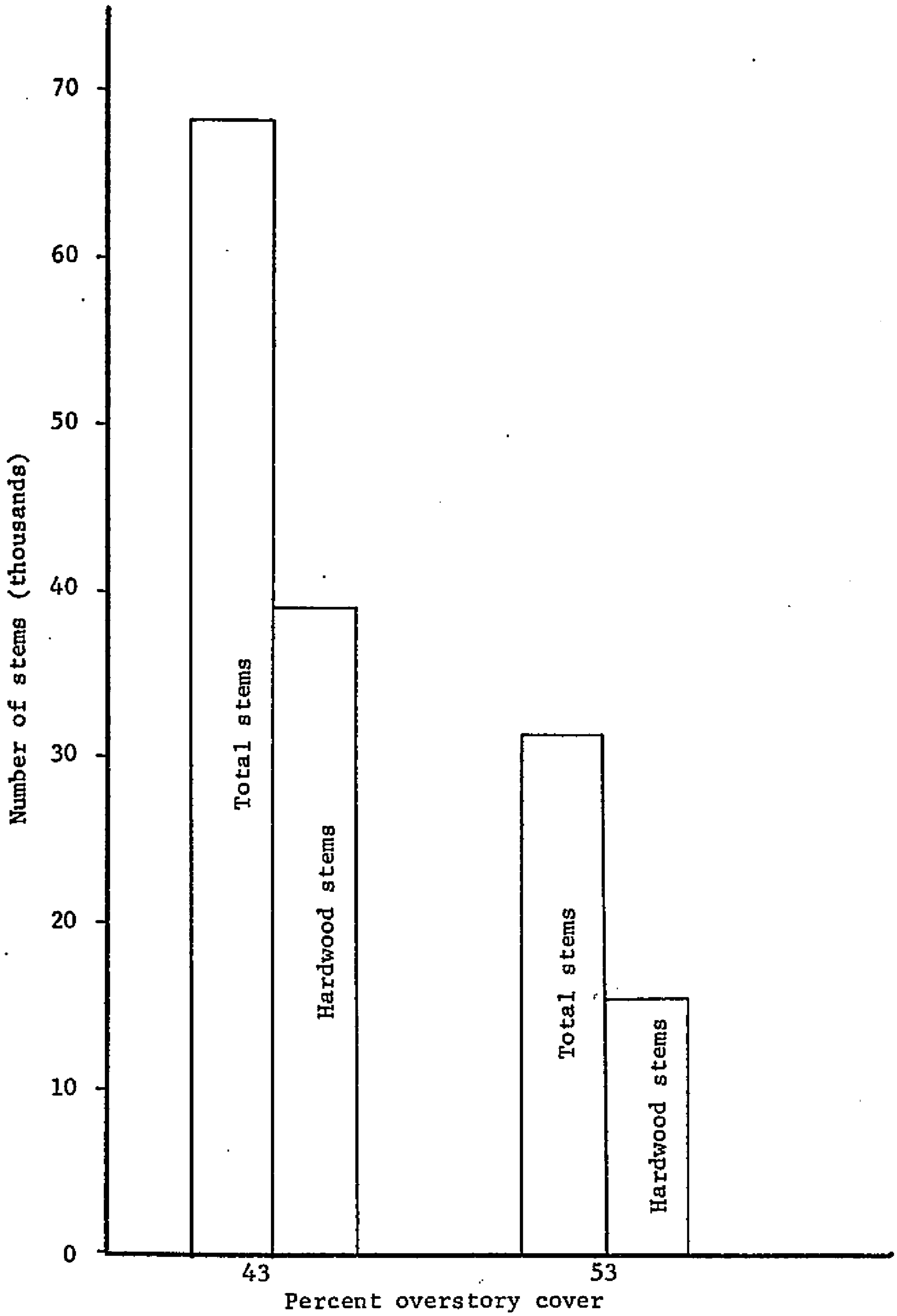


Figure 17. Understory stem totals per acre by percent overstory cover.

in a group in which the overstory cover percentage averaged 43. Stands 5, 7, 4, and 10 were similar in density of the overstory and averaged 53 percent. Although the percentage of overstory cover was determined by ocular estimates rather than actual measurements, any bias that could have occurred would be constant because all estimates were made by the author.

An almost perfect trend is shown in Figure 17. Total stems and hardwood stems decrease in the same ratio with an increase in the percentage of overstory cover. Since light is directly related to the density of overstory cover, these data tend to corroborate the importance of available light to the development of understory vegetation as indicated by the number of stems.

Correlations between the percentage of overstory and the understory cover, and between the percentage of overstory and the grass cover were computed. The following values were obtained when the overstory was correlated with:

understory cover: $r = -0.165^{**}$[1]

grass cover: $r = 0.115^{**}$

The analysis statistically supports the significance of the data presented in Figure 17. As the overstory cover increases in density a statistically significant decrease in the understory cover and in the grass cover occurs.

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[1]** = Significant at P = 0.01

Analysis of the descriptive data by both tabular form and by statistical method points to the possible great influence of light and soil conditions upon understory vegetation. It appears that light and soil are more important than the burning regime to understory development.

The influence of root competition and edaphic factors other than soil drainage were recognized but were not considered in this study. Moreover, crown density has an impact on site conditions other than the amount of light that reaches the understory. Since variables such as those mentioned were not analyzed in the study, an effort was made to minimize their influence by stand groupings.

General Composition of the Understory Vegetation

Data on the composition of the understory were presented in Tables 3 through 22. Scrutiny of these tables reveal some definite trends for several plant species. No single species was dominant over the different soil drainage classes and stand age classes found under a single burning regime. Because of the tolerance differences among plants, the nature of the crown canopy played an important role even though there are many uncontrolled variables. Generally, two or three hardwood species comprised a major part of the total stems tallied in a given stand. Also, the number of vine and herbs with a high frequency of occurrence was small. The number of growing seasons since the last prescribed burn was no doubt important, but direct comparisons could not be made. Previous studies have indicated a reduction in the number of herbaceous species and an increase in the number of woody stems with each additional growing season after a burn.

An important uncontrolled variable, which probably affected the occurrence of herbaceous growth and might have had an influence on height growth of shrub and tree species, was the monthly rainfall totals during the growing season of 1969 (Table 1). Studies have suggested that tree growth is influenced more by the previous year's rainfall than that during the current year of growth increment being measured. Herbaceous vegetation depends primarily on rainfall during the growing season just as agricultural crops do. The drier than "average" months of the growing season might have altered the herbaceous composition to some degree.

Stands Burned Annually

1. Stand 5: This stand was prescribed burned annually for the past 10 years. Study of the data and field observation suggests that late winter burning on an annual basis may "kill" as well as "kill back" hardwood undergrowth (Figure 18). Only eight hardwood species were encountered during the sampling. Shining sumac, persimmon, and southern bayberry were most common. Grass growth was not heavy but it was the primary vegetation on the forest floor. Ten herbaceous species had a frequency percentage of 20 or greater. Ten of the 31 herbaceous and vine species occurred infrequently.

Since the stand history prior to the present burning program is not known in detail, a small number of woody species may have existed

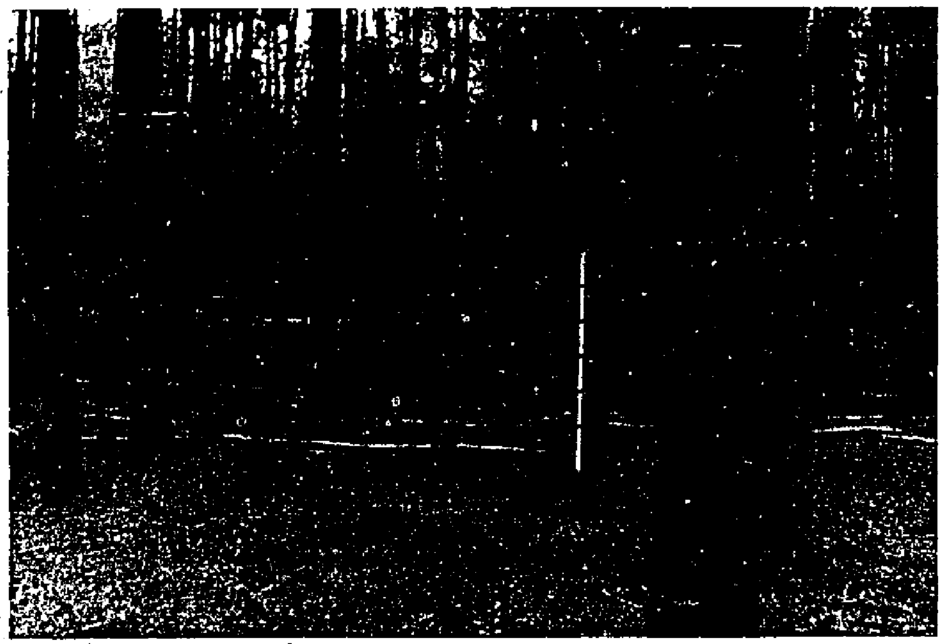

Figure 18. Absence of understory hardwoods after 10 years of annual burning.

at the beginning of the annual burning program. The prescribed burning program could then have prevented an increase in the number of species.

A side effect of the several years of annual burning was the fire damage to the lower part of the bole of many trees. Generally, once a tree has been damaged by fire, each succeeding fire does damage at an increasing rate. Lachmund (1923) pointed out four types of bole injury common in conifer forests after repeated burning: (1) old scars, (2) extensions, (3) new lesions, and (4) hollowing out of old wounds. It would be difficult to classify fire damage into these categories without repeated observation over a period of time.

A sample was taken in this stand without any effort to classify wound type. Those trees on which the bark was missing and blackened wood was exposed were tallied as fire-damaged trees. Fusiform rust most probably contributed to much of the damage. Siggers (1949) found a greater number of new infections of fusiform rust on burned plots than on unburned areas. His study was in an 8- to 9-year-old slash pine stand, and the results may not be valid in the 31-year-old loblolly pine under study. Regardless of cause, the survey found an average of 45 trees per acre damaged out of a total of 180 trees per acre. Thus, after a period of 10 annual burns, 25 percent of the standing trees in a 31-year-old loblolly pine stand have damage of a serious nature (Figures 19 and 20). Burns (1949) stressed a logical assumption that fire scars are more prevalent where repeat burns occur.

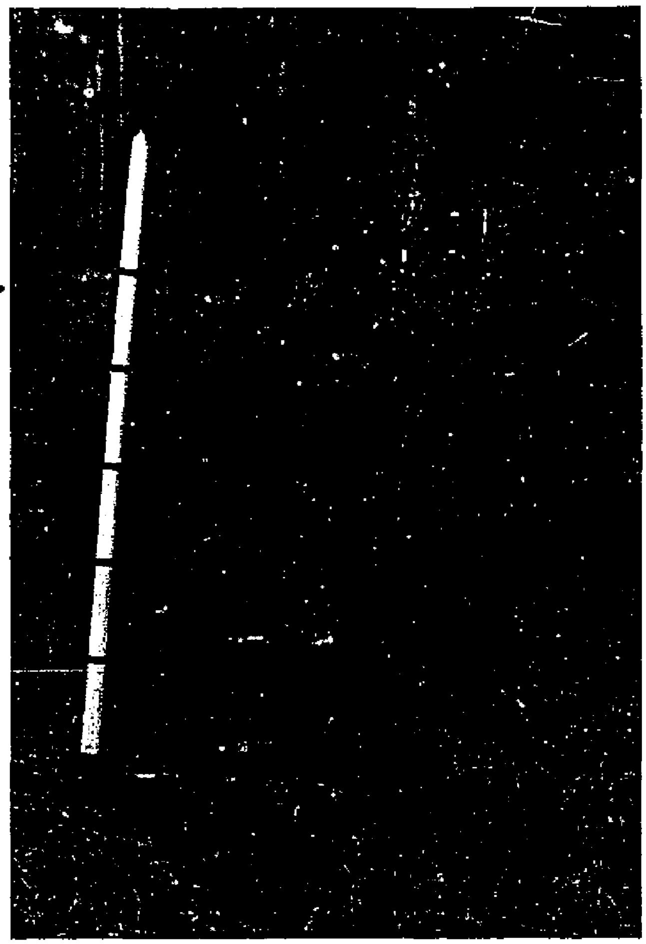

Figure 19. Fire and fusiform rust damage in a 31-year-old stand of loblolly pine burned annually for 10 years.

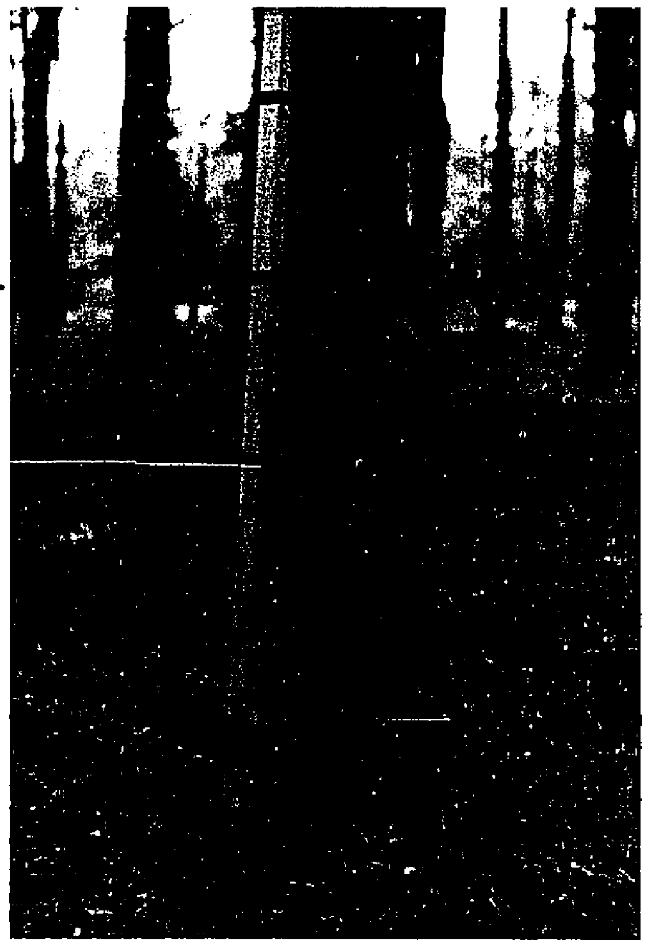

Figure 20. Tree bole damage in stand burned annually for 10 years.

Fire scars can become so serious that structural strength is reduced and wind breakage increased. It appeared that some of the trees in stand 5 had reached this stage. If the wind does not topple these trees, subsequent fires may burn them down. Almost invariably bark charring is highest on the leeward side of the trees. This results from the chimney effect where a convection column rises on the protected side of the tree carrying the heat and flames upward. This condition is most pronounced in headfires (Hare 1961, Fahnestock and Hare 1964). This last point is significant because a hot head fire was permitted in this stand by inexperienced personnel in 1967.

Byram and Nelson (1952) stated that intensity of a fire, the initial vegetation temperature, and the lethal temperature of plant tissue are variables which influence the direct or immediate damage effects of fire. Hare (1965) found fire resistance tends to increase with tree diameter which normally causes an increase in bark thickness.

Burns (1949) stated that, due to the reduced vigor and growth, mature pines are more susceptible to fire scars than are the younger, more vigorous individuals. In the study area this condition was not noticeably true.

While the exposure of wood in hardwoods as a result of fire provides an entrance for decay organisms (Burns 1955), exposure of wood in conifers supplies a larger burning surface, usually supplied with resin, for subsequent fires. The fire-damaged conifer is also easy prey to insects and other organisms.

To conclude from this study that annual burning for a 10-year period results in serious damage to a young timber stand might not be sound. Numerous studies have shown that serious damage is not common. Furthermore, the conditions of the 10 prescribed burns in this stand were not known except that they were in late winter or early spring, and the 1967 fire was more intense than desired.

An infestation of fusiform rust that seemed heavier than normal was observed. A relationship between fire-damaged trees and fusiform rust infection probably existed but the extent could not be determined. The removal of cankered trees could have reduced the danger of fire damage to tree boles in this stand. Possibly, better control of the burning operation could have prevented some of the damage directly due to fire.

Annual burns in the other stands studied caused no noticeable fire damage. The type of fire and intensity of the prescribed burn appeared to be most influential in stand 5. The site sampled may have been an isolated example of poor burning technique. Cursory observation in other areas of this stand which had received the same program of burning failed to show serious damage due to prescribed burning even though cankered trees were common.

2. Stand 2: Two species -- American beautyberry (54 percent) and southern bayberry (33) percent) -- made up 87 percent of the total shrub and tree stems in stand 2. A total of 14 separate species were found in the sampling. A heavy cover of herbaceous vegetation with some vines consisted of 14 species with a frequency

percentage of 20 or larger. Panicum sp. and waxweed were found in almost every subplot. The total vegetation composition of the understory provided excellent conditions for grazing animals or for wildlife. Control of the more undesirable hardwoods appeared excellent. Even though there were two seasons of growth at the time of sampling, almost all of the stems tallied measured under 3 feet in height.

3. Stand 7: This stand on moderately well-drained loessal hills soil, had been burned annually for the past 6 years. Surprisingly, more than 13 percent of the counted stems were over 3 feet in height. Evidence of a midstory indicated the lack of intensive management in the past (Figure 21). The fire history prior to the present burning program was not established. An examination of species composition failed to show a clear division which might be used to note control of undesirable hardwoods. Shining sumac (13 percent) was prominent but was exceeded by sweetgum (36 percent) and dogwood (14 percent) in proportion of total stems. American beautyberry was obvious even though its stem count was less than 5 percent of the total.

Twelve herbaceous species had a frequency percentage of 20 or more. Only six species out of a total of 33 were considered rare in occurrence (found only in 1 subplot). Legumes such as beggar lice, partridge pea, and milkpea had a wide distribution. Grass cover was good and the area appeared to be grazed only lightly, if at all. A more distinct pattern of species division might occur in this stand after two or more additional prescribed burns.

Figure 21. Several hardwood species occur in the understory on well-drained loessal hills soils even after six annual burns.

4. Summary of stands burned annually: The vegetation in the three stands burned annually was characterized by more differences than similarities. The total number of herbaceous and vine species was comparable for each stand, but composition and height of the understory varied. Several individual species were represented in each stand, but the number or frequency of occurrence showed a wide range. The contrasts between stands 2 and 7 were probably due to soil differences. Analysis of variance tests isolated the soil variable for individual shrub and tree species, so it seems logical to conclude that differences in the overall makeup of the understory are due to the soil factor.

The intensive burning program was sufficient to account for the nature of the understory in stand 5. Hardwood stems were so limited that cursory observation might indicate a complete absence. Very few of the enumerated stems were more than 18 inches in height. Figure 18 is illustrative of the typical conditions found in this stand.

Stands Burned Periodically

1. Stand 1: In stand 1 a total of 13 hardwood species were recorded, but three species -- American beautyberry (42 percent), persimmon (22 percent), and sweetgum (12 percent) -- comprised 76 percent of the total stems. Blackgum (9 percent) and southern bayberry (7 percent) constituted an additional 16 percent. These five species accounted for about 92 percent of the total stem count. Study of these data and Figure 22 shows that American beautyberry dominates the understory in this stand.

Figure 22. Good control of the understory with periodic burning.

The vine and herbaceous vegetation was quite varied in stand 1, but only five species occurred regularly. The vine component was greater in this stand than in most others. Waxweed and Panicum sp. formed a dense cover of the ground over most of the stand.

2. Stand 4: This stand was last burned in 1967. Four prescribed burns had been made on an average of every three years. Southern bayberry (28 percent), shining sumac (16 percent), sweetgum (13 percent), sparkleberry (8 percent), and American beautyberry (8 percent) combined accounted for 73 percent of all hardwood stems. Ten percent of the stems exceeded 3 feet in height and several stems exceeded 6 feet in height (Figure 23). The 15 tree and shrub species sampled might have been slightly more than that expected in one growing season after a prescribed burn.

The large number (48) of herb and vine species in stand 4 was not so unusual when the species composition was examined. Ten equaled or exceeded a frequency percentage of 20, and 18 species were considered rare in occurrence. The large number was probably due to three growing seasons after the last prescribed burn. Legumes were not abundant but were well represented. Cattle were observed in the general area of the stand, which had a good grass cover.

3. Stand 10: The periodic burning program in stand 10 had maintained the understory at a manageable level. The three seasons' growth since the last prescribed burn was shown by the 20 percent of total hardwood stems over 3 feet in height and by the relatively large number of species contributing an appreciable percentage of the total

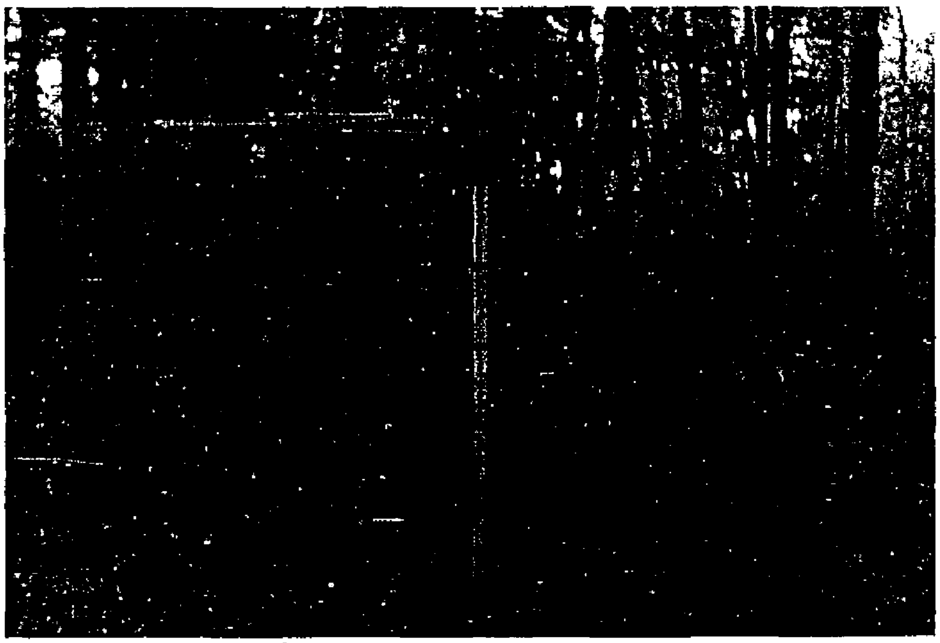

Figure 23. Three seasons' growth of understory in a young loblolly pine stand periodically burned. Lines on pole are 1 foot apart.

stems (Figure 24). Three species -- American beautyberry (22 percent), southern bayberry (17 percent), and sweetgum (13 percent) -- were most common, although six other species made up a large part of the total stems. The large number of hardwood species was comparable to stand 4 which also had three seasons of growth since the last prescribed burn.

Vine and herbaceous growth was similar in stands 10 and 4. Each had a large number of species represented and a significant number which occurred infrequently.

4. Stand 6: The conservative periodic burning program in stand 6 is signified by the large number of hardwood species (18) encountered, the amount of the understory over 3 feet in height, and the number of hardwood stems in the midstory. Eight years had elapsed between the last two burns, and this time period was long enough for substantial height growth to occur. The prescribed burn in 1969 was most effective and caused no visible damage to the boles of the trees in the overstory. No living hardwood stems under 2 inches were observed (Figure 25). Sprout growth was proliferous and lush. Southern bayberry (35 percent) and yaupon (10 percent) had the greatest number of stems, but several species were close in numbers.

Sixteen herb and vine species had a frequency percentage equal to or greater than 20, while twelve species occurred infrequently. Legumes were abundant over the stand. Grass was widely distributed but not especially plentiful due to the competition of the numerous other plants. Browse conditions for deer were excellent and the

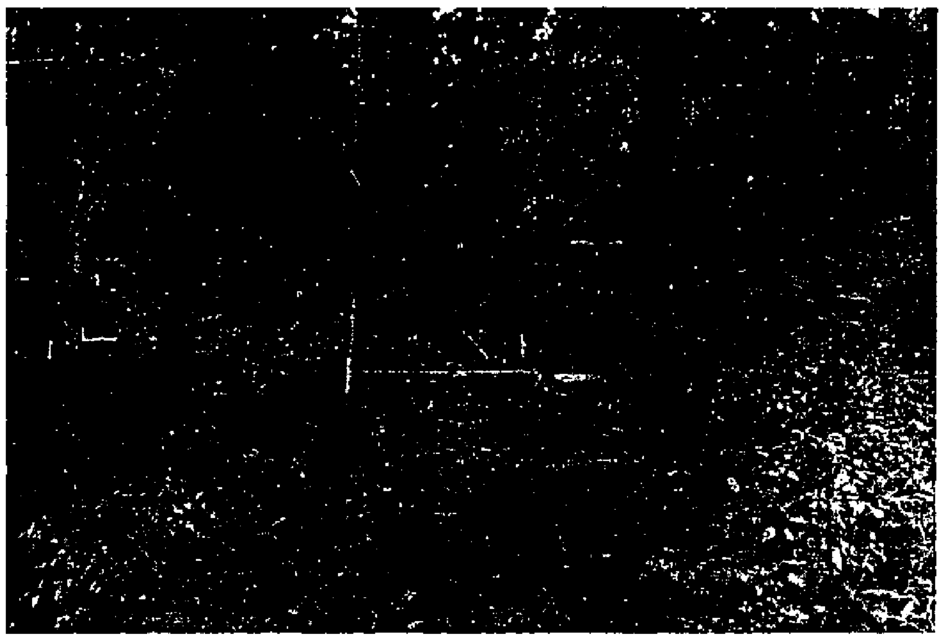

Figure 24. Effect of periodic burns on the development of hardwood understory. Stand was burned three years previously.

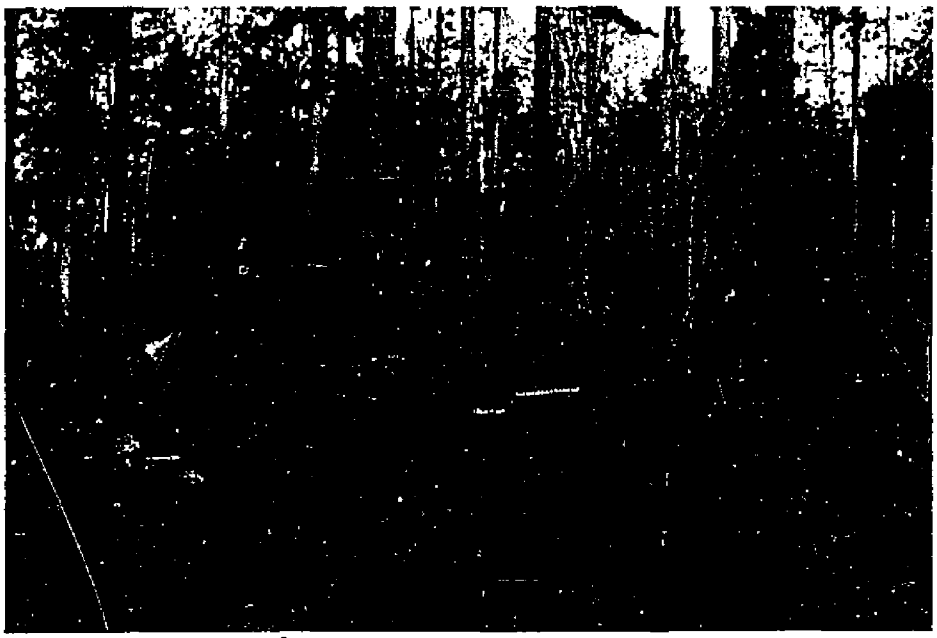

Figure 25. Vigorous resprouting in a stand in the loessal hills burned periodically three times. Last burn was in 1969.

overall conditions for other wildlife appeared to be good. This stand might illustrate adequate control of the understory for timber management purposes with a minimum number of prescribed burns.

5. Summary of stands burned periodically: American beautyberry comprised about the same percentage of total stems in stands 6 and 7, but southern bayberry, the dominant species in stand 6, was lacking in stand 7. The stand ages and soil types were similar for the two stands, but the burning regimes and percentage of overstory cover were different. The number of species encountered in the two stands were comparable. It does not seem feasible that six annual burns would eradicate southern bayberry. The possibility exists that southern bayberry was not present in stand 7 just prior to burning but this seems unlikely since it was so prominent in nearby stands. Stand 6 had far more hardwood stems per acre than any other stand studied. Light and soil differences were probably responsible.

Unburned Stands

1. Stand 3: The youngest stand studied, stand 3, had an average age of 26 years. The numerous species (19) of the understory and midstory were evenly distributed except for southern bayberry, laurel oak, and sweetgum which predominated with a combined total of 57 percent of the total stems. A characteristic of this stand was the multistory effect which was lacking in stands prescribed burned. The midstory was prominent and blended the understory with the main canopy (Figure 26). Southern bayberry was most common in both the midstory and understory.

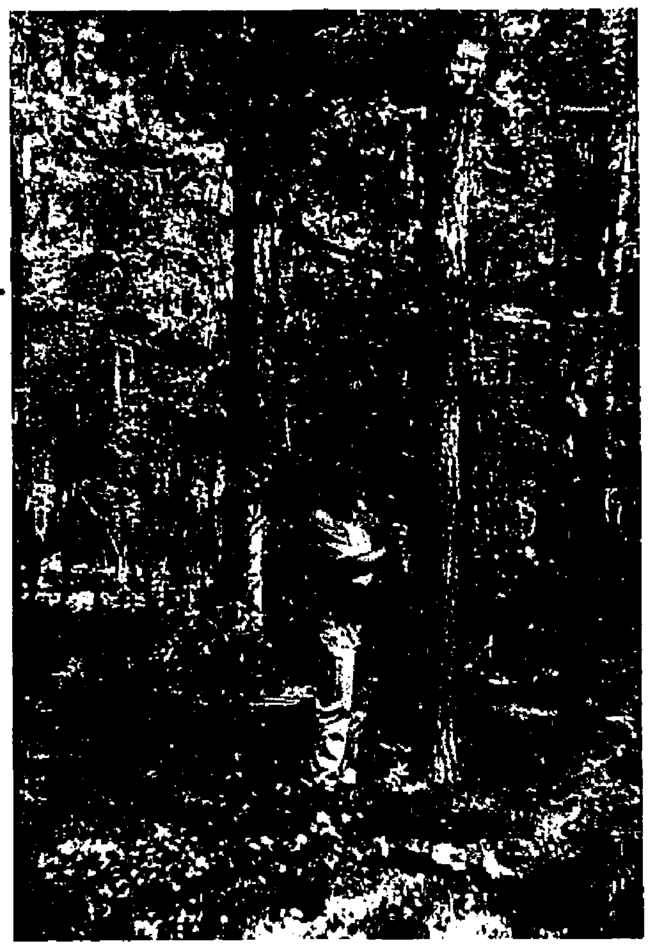

Figure 26. Dense hardwood midstory and relatively clean forest floor in a 26-year-old unburned loblolly pine stand.

Light competition was intense in stand 3 and this factor plus the accumulation of organic matter limited the number of vine and herb species. Only four species had a frequency percentage greater than 20. The 16 species represented was the smallest number recorded in all the stands.

2. Stands 8 and 9: These stands are representative of conditions that result when little or no management is applied, and especially when fire is excluded from pine stands (Figures 27, 28, and 29). Stand 8 was composed of 25 hardwood species of which seven made up 75 percent of the total stems in the understory and midstory. No single species dominated as was often the case in burned stands. Stand 9 included 30 hardwood species with red maple occurring most often. Approximately 10 species accounted for the major portion of the total stems. Four herb or vine species in stand 8 and six species in stand 9 had a frequency percentage greater than 20. As the photographs vividly portray, the forest floor was not cluttered with herbs and vines; most vines grew up into the trees.

Stands 8 and 9 appear to be moving toward a climax stage of vegetation development (Figure 30). Neither stand had pine regeneration due to insufficient light reaching the forest floor and the heavy accumulation of organic debris on the surface. The overall appearance was one of hardwoods awaiting the removal of the overstory pine by either man or natural causes.

Halls and Homesley (1966) described a mature pine-hardwood forest in southeastern Texas that was comparable to both stands 8 and 9.

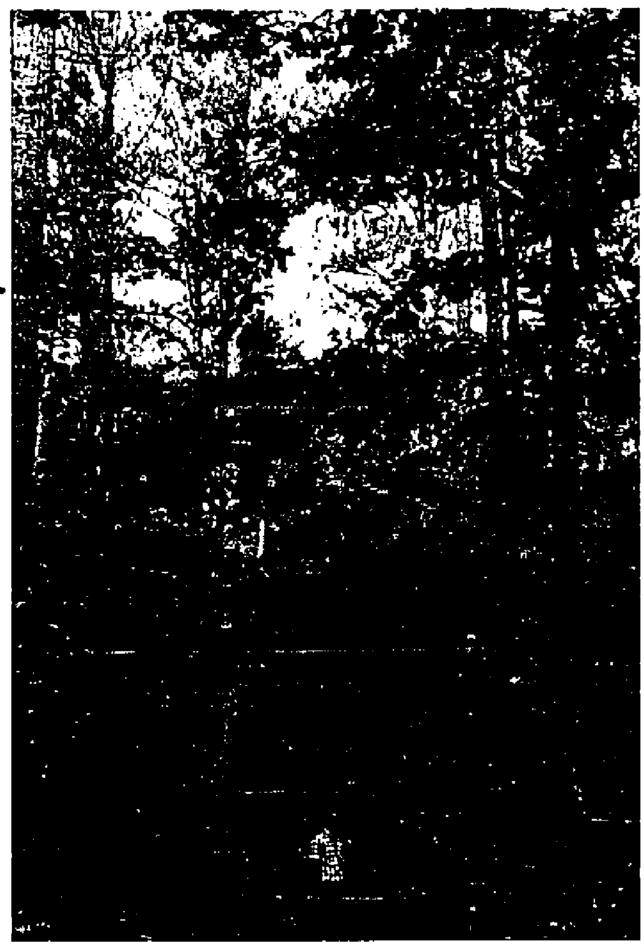

Figure 27. Multistory effect in an unburned loblolly-shortleaf pine-hardwood forest.

Figure 28. Limited development of herbaceous vegetation in an unburned loblolly pine-hardwood stand.

Figure 29. Heavy plant growth in an unburned loblolly pine-hardwood stand.

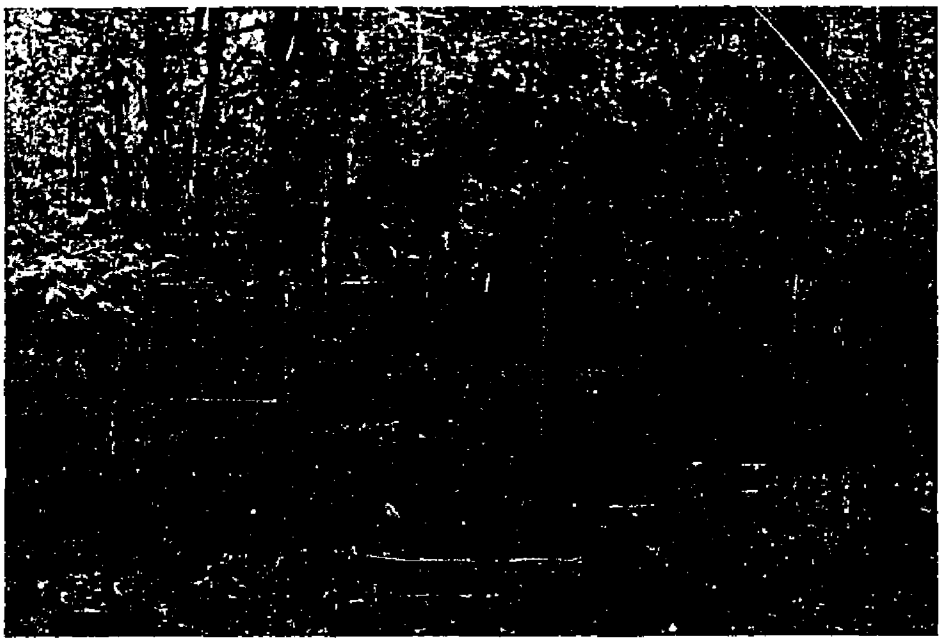

Figure 30. Magnolia, oak, and sparkleberry in an unburned loblolly-shortleaf pine-hardwood stand.

They recorded 20 hardwood species, six principal herbaceous species, and vines similar to those in the present study.

3. Summary of unburned stands: The three unburned stands had much in common. They differed mainly in age. Each had a large number of hardwood species and a relatively small amount of herbaceous vegetation. The number of vines differed little from burned stands; however, they were much larger on the unburned sites. The data show considerable differences in the number of stems per acre, the number of a given species, and different height classes in burned and unburned stands.

Several factors influence the understory composition. Soil drainage classes, stand age, overstory cover density, height of the canopy, and the amount of organic litter on the forest floor all have an effect on the vegetation composition.

Most plant communities are so complex that a clear-cut analysis of the relative importance of various components in the community is most difficult. When the many mechanisms active in the plant community are exposed to the effects of burning, the final result is nearly impossible to predict.

Went *et al*. (1952) and Sweeney (1969) discussed some of the factors which influence plant distribution after burning. These factors may be summarized as follows: the heat tolerance of dry seed, the variation of seed dormancy by species (some seed need fire to break dormancy), the seedbed conditions (litter accumulations often limit growth of various plant species which may become plentiful when litter is removed by burning), sprouting ability of hardwoods, and the flowering and seed production of some perennials that are encouraged when the dominant woody species are removed by burning. The burning interval, the total number of burns, and the nature of each individual burn are also influential in plant distribution.

The preceding stand analyses provide useful information that may be supplemented with the results of statistical tests for the best possible interpretation of the effects of burning on the understory vegetation. Examination of the graphic illustrations and stand data indicates that soil drainage conditions, overstory cover, and burning affect the vegetation in number of stems per acre, in the size (height) of stems, and in the ratio of pine seedlings to hardwood growth in the understory. Study of stand data provided information pertaining to species composition. A small number of shrub and tree species generally dominated the understory. Also, few vine and herbaceous species occurred regularly.

Statistical analyses were used to detect differences among selected plant species in the ten stands. The tests used included analysis of variance with orthogonal comparisons, chi-square, and correlation analysis. Each statistical test has certain shortcomings, but results of tests provide useful supplemental information helpful in explaining trends or contrasting patterns.

Analysis of Variance for Selected Woody Species

Analysis of variance with orthogonal comparisons for the number of stems of 13 selected understory shrub and tree species revealed several differentiating conditions which help to explain plant distribution in the study area. Statistically significant differences occurred among stands for all species tested with the exception of willow oak. Also, statistically significant differences among plots within stands were recorded for all species except water oak and southern red oak (Table 23). Orthogonal comparisons were used to partition the variation and isolate the primary cause of variation in the plant distribution (Table 24). Species are discussed separately due to the wide variation in response to treatments.

American Beautyberry. -- It seemed logical to first compare the number of stems of this species growing in burned stands with those in unburned stands. The comparison showed that burning resulted in a statistically significant increase in the number of American beautyberry stems in the understory. These results are similar to previous studies where American beautyberry was characteristic of burned sites. In one "unburned" stand of this study American beautyberry was found in one sample plot. It was later determined that a small surface fire (approximately one-tenth acre in size) had occurred about 10 years previously. This one spot happened to coincide with a sample quadrat. Careful observation of the stand revealed no other occurrences of this species. This illustration shows the response of American beautyberry to fire.

Table 23. Analysis of variance for number of stems of selected woody species

Source	d.f.	American beauty-berry	dogwood	sweetgum	yaupon	southern bayberry	sumac	*Vaccinium* sp.
		Mean Squares[a]						
Stand (Treatments)	9	56.46**	8.52**	12.53**	7.68**	93.71**	2.16**	7.10**
3,8,9 vs 1,2,4,5,6,7,10	1	99.48**	1.19	15.11	3.15	93.50**	5.13**	4.40
2,5,7 vs 1,4,6,10	1	2.29	0.67	0.27	13.49**	70.20**	0.00	6.88*
5 vs 2,7	1	92.97**	3.19	22.93*	0.01	28.83*	0.96	0.00
2 vs 7	1	216.10**	9.58	65.57**	0.04	98.00**	8.41**	0.49
3 vs 8,9	1	0.16	2.60	0.33	0.33	3.20	0.05	8.33*
8 vs 9	1	0.01	7.81	1.00	1.00	0.49	0.00	4.84
1 vs 4	1	84.65**	0.00	1.95	0.09	3.61	4.41*	3.24
1,4,10 vs 6	1	12.33	52.12**	5.61	48.17**	543.40**	0.48	31.74**
1,4 vs 10	1	0.22	0.00	0.85	2.80	0.21	0.00	1.08
Plot/stand	90	6.17**	2.88**	4.28**	1.54**	5.86*	0.72**	1.54**
Subplots/plot/stand	400	3.63	1.48	1.42	0.87	4.57	0.28	0.92

[a]** = Significant at P = 0.01
* = Significant at P = 0.05

Table 23 (Continued)

Source	d.f.	red maple	water oak	willow oak	southern red oak	persimmon	blackgum
		Mean Squares[a]					
Stand (treatments)	9	6.54*	1.31**	0.19	0.31*	2.16**	1.71*
3,8,9 vs 1,2,4,5,6,7,10	1	12.27	0.58		0.35	1.84	0.86
2,5,7 vs 1,4,6,10	1	6.56	0.00		0.09	3.31*	5.01*
5 vs 2,7	1	0.01	1.77*		0.08	0.33	0.65
2 vs 7	1	0.04	0.25		0.09	0.04	1.00
3 vs 8,9	1	19.77*	0.12		0.05	0.00	0.27
8 vs 9	1	0.81	0.16		0.00	0.09	1.21
1 vs 4	1	0.09	0.01		0.01	7.85**	3.24*
1,4,10 vs 6	1	18.72*	8.88**		2.04**	2.94*	2.28
1,4 vs 10	1	0.56	0.00		0.08	3.00*	0.85
Plot/stand	90	3.14**	0.41	0.13*	0.14	0.49**	0.78*
Subplot/plot/stand	400	0.72	0.36	0.10	0.13	0.17	0.54

[a]** = Significant at P = 0.01

* = Significant At P = 0.05

Table 24. Data used in orthogonal comparisons

Stand[a]	Treatment	Soil drainage class[b]	Timber type and stand age
5	Burned annually	S_2	Loblolly pine (25-35 years)
2	Burned annually	S_2	Loblolly pine (40-50 years)
7	Burned annually	S_3	Loblolly pine (40-50 years)
1	Burned periodically	S_1	Loblolly pine (40-50 years)
4	Burned periodically	S_1	Loblolly pine (25-35 years)
10	Burned periodically	S_2	Loblolly pine (40-50 years)
6	Burned periodically	S_3	Loblolly pine (40-50 years)
3	Unburned	S_2	Loblolly pine-hardwood (25-35 years)
8	Unburned	S_2	Loblolly-shortleaf pine-hardwood (40-50 years)
9	Unburned	S_1	Loblolly pine-hardwood (40-50 years)

[a]Stands are numbered in the order of sampling in the field.

[b]S_1 represents poorly drained flatwoods soils, S_2 represents somewhat poorly drained terrace soils with fragipans, S_3 represents moderately well-drained loessal hills soils.

Both light conditions and soil drainage conditions are factors of great importance to the presence of American beautyberry. When stands burned annually with soil classes 2 and 3 and 40- to 50-year-old trees (stands 2 and 7) were compared with a similarly burned stand with soil class 2 and 25- to 35-year-old trees (stand 5) statistically highly significant differences resulted. The significantly larger number of American beautyberry stems in the understory of the older trees (stands 2 and 7) with less dense crowns indicates the response of this species to increased light. This variation was further partitioned when the two mature timber stands on soil classes 2 and 3 were compared (stand 2 vs. stand 7, Table 23). The statistically significant increase of American beautyberry on soil class 2 demonstrates the preference of this species for soils classed as somewhat poorly drained terrace soils with fragipans.

The difference in the occurrence of American beautyberry in periodically burned stands of different ages but growing on soils of the same drainage class further indicates the effect of light on this species. When stand 1 was compared with stand 4, the larger number of American beautyberry stems on stand 1 was statistically highly significant. It seems safe to assume, therefore, that American beautyberry does better under a high, open canopy than under a low, dense canopy.

There was no discernible pattern of occurrence of this species between stands burned annually and those burned periodically.

Dogwood. -- Study of the data indicates that dogwood reacted more to differences in soil drainage than to other stand conditions in the study. When stand 1 on soil class 1 and stand 10 on soil class 2 (both with 40- to 50-year-old trees) were combined with stand 4 (25- to 35-year old trees) on soil class 1 for a comparison with stand 6 (trees in the 40- to 50-year age class on moderately well-drained loessal hills soil - drainage class 3) there was a statistically significant difference. The significantly greater number of dogwood stems in the understory of stand 6 well illustrates the importance of the soil drainage factor to this species.

Sweetgum. -- This species reacted to both available light and soil conditions. Statistically significant differences occurred in annually burned stands which differed in soil drainage and age of trees. In the comparison of stand 5 with stands 2 and 7, the larger number of sweetgum stems in the older stands was statistically significant. Greater differences resulted when two annually burned stands with trees in the 40- to 50-year age class but with different soil drainage were compared (stand 2 vs. stand 7). The greater number of sweetgum stems on the better drained soils of stand 7 was statistically highly significant. Both stands 2 and 7 had been burned at least six times, so burning apparently was not an important influence in the difference in the number of sweetgum stems. The percent overstory cover for the two stands did not differ appreciably, which indicated that light was not as critical to the distribution of this species as to such species as American beautyberry. Soil drainage differences apparently were most important to the number of sweetgum stems in the understory of stands 2 and 7.

Yaupon. -- This important game food reacted to burning intervals as well as to increased light. Highly significant differences resulted when annually burned stands (stands 2, 5, and 7) were compared to those sites burned periodically, especially on the better-drained soils containing mature trees. An examination of these results suggests that yaupon decreases in the understory as burning intensity increases. The high occurrence in stands 6 and 10 (40- to 50-year age class) was in contrast to the absence of yaupon in stands of the 25- to 35-year age class. Since a good distribution of yaupon occurred under mature trees growing on soil class 2, but no stems occurred under the more dense canopy of the younger trees growing on similar soil, light apparently is very important to the establishment and growth of this valuable game species.

Southern Bayberry. -- The burning treatment of the stand, available light as indicated by height and overstory cover percentage, and soil drainage all seemed to influence the distribution of this species. When the unburned stands (3, 8, and 9) were compared with the burned stands (1, 2, 4, 5, 6, 7, and 10), there occurred a statistically highly significant increase in the number of stems in the burned stands. This result was expected, since burning results in sprouting from the rootstocks when hardwood stems are killed back. A comparison between stands burned annually (stands 2, 5, and 7) and those burned periodically (stands 1, 4, 6, and 10) revealed a statistically highly significant increase in the number of southern bayberry stems in stands burned periodically. Further partition of the variation among stands burned annually indicated that light and soil drainage were also important to southern bayberry. When stand 5 (25- to 35-year age class) on soil class 2 was compared with the older stand 2 on soil class 2 and stand 7 on soil class 3, a statistically significant increase in the number of stems was noted in the stands with 40- to 50-year old trees and higher crown canopies (particularly stand 2). Since higher canopies permit more light to the forest floor than a low canopy of similar percent cover, the comparison between stands burned annually suggests the importance of light to the growth and development of southern bayberry.

Soil drainage may also be important to southern bayberry but the statistical tests were not conclusive in the study. A comparison between annually burned stand 2 with 40- to 50-year-old trees on soil drainage class 2 and stand 7 with similar aged trees but on soil class 3 showed a statistically highly significant increase in the number of southern bayberry stems in stand 2 (somewhat poorly drained soils). However, when the periodically burned stands 1, 4, 6, and 10 were compared on the basis of soil drainage, statistically highly significant differences were recorded due to the increased stem totals in stand 6 (moderately well-drained loessal hills soil). Since there were no statistically significant differences between the periodically burned stands 1 and 4 (soil class 1) vs. stand 10 (soil class 2), but statistically highly significant differences between stands 1, 4, and 10 (soil classes 1 and 2) compared with stand 6 (soil class 3), the importance of soil to the occurrence of southern bayberry is not clear.

Stand 6 on moderately well-drained loessal hills soil also had the lowest percent overstory cover of stands in the study. It appears that light is more important to southern bayberry than soil drainage. The only stand in the study that did not show the presence of this species was stand 7, a mature loblolly pine stand burned annually and located on moderately well-drained loessal hills soil. Every other stand had some southern bayberry present.

Sumac. -- This species showed a definite preference for stands prescribed burned and for the better drained soils; yet on soil of the same drainage class sumac occurrence under conditions of periodic burning was significantly greater in the younger stands than in the older stands. The only explanation that seems logical is that the understory under the younger stand (stand 4) had three seasons' growth since the last burn compared to one season's growth under the mature trees. Basal area for the two stands was similar and site index differed little. Actually, stand 1 had more available light to the understory than stand 4. Sumac does well in open, well-lighted areas, yet it was not always found under such conditions in the study area. It may be that sumac could be used as an indicator of burning control on well-drained soil; however, no definite pattern was established on the poorly drained soils in the study area.

Vaccinium sp. -- Some trends were evident in the distribution of Vaccinium sp. Statistically significant differences between stands burned annually (stands 2, 5, and 7) and those burned periodically (stands 1, 4, 6, and 10) were the result of the small number of stems in stands burned annually rather than any regular distribution on stands burned periodically. Stands 1 and 10 had no stems in the sample plots while stands 4 and 6 had rather high counts. Stand 4 is 25 - 35 years of age and located on poorly drained flatwoods soil while stand 6 is 40- to 50-year-old loblolly pine growing on well-drained loessal hills soil.

A comparison of unburned stands (3 vs. 8 and 9) showed statistically significant differences. The low frequency of occurrence of *Vaccinium* stems in the 25- to 30-year-old loblolly pine on stand 3 was contrasted by the high number of stems in the 40- to 50-year-old trees in stands 8 and 9. Since differences in soil drainage were not involved in this comparison, more available light under the older and higher trees may have been responsible for the statistically significant increase in *Vaccinium* stems in stands 8 and 9.

The most obvious differences in variation were due to soil drainage. In a comparison of stands burned periodically, the moderately well-drained loessal hills soil (stand 6) with the lowest percent overstory cover produced the best growth of these species. It appears that *Vaccinium*, like sumac, does well on the drier soils, and does not withstand annual burning well. Distribution of sumac and *Vaccinium* sp. might show a different pattern under other edaphic conditions with burning regimes similar to those in this study.

Red Maple. -- This species reacted to differences in both light and soil drainage. In a comparison of unburned stands (stand 3 vs. stands 8 and 9) on similar soil types but with different aged trees

(25 - 35 years vs. 40 - 50 years), the statistically significant differences were accounted for by the higher number of stems under the older trees of stands 8 and 9. When stands burned periodically were compared, more stems were counted on the moderately well-drained loessal hills soils (stand 6) than on the poorly drained flatwoods soils (stands 1 and 4) or somewhat poorly drained terrace soils with fragipans (stand 6). This increase in the occurrence of red maple due to better drained soil was statistically significant. Soil moisture, as reflected by drainage conditions, and available light, as indicated by the percent overstory cover, appeared to be primary factors in the distribution of red maple.

Oaks. -- Although an analysis of the data indicates statistically significant differences in the occurrence of water oak on stands burned annually, the results are somewhat difficult to explain. As shown in Table 23, stand 5 (25 - 35-year age class) was compared with stands 2 and 7 (40 - 50-year age class). Few stems of any species occurred on stand 5; therefore, any conclusion or even speculation is difficult to make. Soil differences on stands burned annually did not appear to be very important to the occurrence of water oak, but further testing is needed. When the occurrence of water oak on periodically burned stands was compared, soil differences and/or available light were important, and highly significant differences resulted from the comparison. The comparison included stands 1, 4, and 10 on poorly or somewhat poorly drained soils versus stand 6 on moderately well-drained loessal hills soils. Stand 6 also had the lowest percent overstory cover of any stand in the study. The statistically significant increase in water oak stems in stand 6 compared to stands 1, 4, and 10 was due primarily to soil drainage conditions, although light probably was also a factor. The large number of water oak and other hardwood stems in stand 6 was probably in part due to the relatively long period between the previous two prescribed burns (an 8-year interval). This time span was sufficiently long for several tolerant species to become well established. Resprouting after the "kill back" of the most recent prescribed burn was proliferous.

Orthogonal comparisons were not made for willow oak, since no statistically significant differences resulted among stands. The largest number of stems occurred in stand 9, an unburned 40- to 50-year-old loblolly pine-hardwood stand on poorly drained flatwoods soil.

Southern red oak reacted like water oak to periodic burning. A statistically significant increase in the number of southern red oak stems was noted on the moderately well-drained loessal hills soils (stand 6) when compared with the poorly drained soils (stands 1, 4, and 10). These results support previous studies that southern red oak prefers moderately well-drained to well-drained soils. The importance of light was not tested in this comparison, but light appeared to be influential in the occurrence of southern red oak.

<u>Persimmon</u>. -- This intolerant species was significantly affected by burning intervals. A comparison of stands burned annually with those burned periodically indicated a statistically significant

difference in the occurrence of persimmon. Stands burned annually averaged fewer stems per acre compared with stands burned periodically, which seems to indicate that persimmon is not a very fire-resistant species.

Persimmon was one of the four species that showed high requirements for light. In a comparison of stand 1 (40- to 50-year-old stand) with stand 4 (25- to 35-year-old stand), both of which were on the same soil type and had been periodically burned, a statistically highly significant difference was noted. The statistically significant difference obtained was attributable to the increase in the number of persimmon stems in stand 1.

Apparently, persimmon is very sensitive to soil drainage. When periodically burned stands were compared (stands 1, 4, and 10 on poorly or somewhat poorly drained soils vs. stand 6 on moderately well-drained soil), significant differences resulted. The statistically significant increase in the number of persimmon stems in the stands on poorly drained soils, particularly in stand 1, is not clearly understood. Persimmon is an intolerant species and the competition within the understory might be more important than the differences in overstory cover.

The importance of soil drainage was indicated by the previous comparison and by the comparison between three stands burned periodically but with minor differences in soil drainage. The statistically significant larger number of persimmon stems in stands 1 and 4 compared with stand 10 indicated a sharp reaction to minor differences in soil drainage. Competition in the understory was no doubt important, but this variable could not be tested in the statistical framework of the study. Based on the data collected in this study persimmon was the most sensitive of the 13 species to environmental changes.

Blackgum. -- The statistically significant increase in number of blackgum stems in stands burned periodically compared to stands burned annually indicates the inability of this species to withstand annual burning. Blackgum is a relatively tolerant species, yet a difference in available light apparently affected its frequency of occurrence. Two periodically burned stands on poorly drained flatwoods soils were compared (stand 1 with 40- to 50-year-old trees vs. stand 4 with 25- to 35-year-old trees). The larger number of blackgum stems in stand 1 evidently was due to more available light reaching the forest floor in that stand than in stand 4.

Correlation Analysis for Selected Woody Species

Goodall (1952) stressed the need for correlation between the occurrence of different plant species. The overstory density was correlated with selected shrub and tree species. Also, correlations between individual shrub and tree species were calculated and correlation coefficients expressed. The following is a list of the statistically significant correlations:

	r values
Overstory density: American beautyberry	-0.094*
Overstory density: southern bayberry	-0.180**
American beautyberry: water oak	0.148**
American beautyberry; southern red oak	0.094*
Dogwood: yaupon	0.138**

	r values
Dogwood: blackgum	0.095*
Dogwood: sumac	0.089*
Yaupon: blackgum	0.088*
Yaupon: persimmon	0.106*
Yaupon: sumac	0.098*
Southern bayberry: blackgum	0.093*
Southern bayberry: red maple	0.161**
Blackgum: red maple	0.100*

The statistically significant negative values indicate that when the overstory density (cover percentage) increases, there is a significant decrease in the number of American beautyberry and southern bayberry stems in the understory.

An increase in American beautyberry stems was accompanied by a statistically significant increase in water oak and southern red oak stems. Since these oaks are relatively tolerant species, their occurrence under open-clump growth of American beautyberry might be expected.

Dogwood is high on the tolerance scale. When the number of dogwood stems increased, statistically significant increases in yaupon, blackgum, and sumac also occurred. These species respond well to increased light as a result of prescribed burning. Sumac is considered a relatively intolerant species that grows best in exposed locations.

Sweetgum and yaupon are about midway on the tolerance scale, so an increase in one might accompany increased growth in the other. Sweetgum and yaupon grow reasonably well in limited light conditions and respond rapidly when released.

An increase in the number of yaupon stems was accompanied by statistically significant increases in blackgum, persimmon, and sumac. Study of the data indicates that these four species occur together in large numbers in stands not burned too intensely. The four species may differ somewhat in tolerance, but each increased in number of stems as light was increased.

Southern bayberry, blackgum, and red maple are quite tolerant and occurred together in both burned and unburned stands. An increase in the number of stems of one of these species was paralleled by increases in the stem totals of the other two species.

Other species are undoubtedly correlated statistically; however, the species tested in this study were limited to the 13 most commonly occurring shrubs and trees in the understory of the stands studied.

Indicator Plant Potential

Study of stand composition and statistical tests of individual species indicate that southern bayberry, American beautyberry, sumac, yaupon and *Vaccinium* sp. have possibilities for use as plant species indicative of prescribed burning levels. Since there are so many variables involved in a given stand, several factors might influence the species composition. Data presented in Figures 31, 32, and 33 are stem totals for the five species mentioned above by burning interval, by soil drainage class, and by percent of overstory cover. An examination of Figure 31 suggests that American beautyberry is more persistent under annual burning than southern bayberry; however, an opposite trend is indicated in stands burned periodically. The number of sumac stems was almost identical under annually and periodically

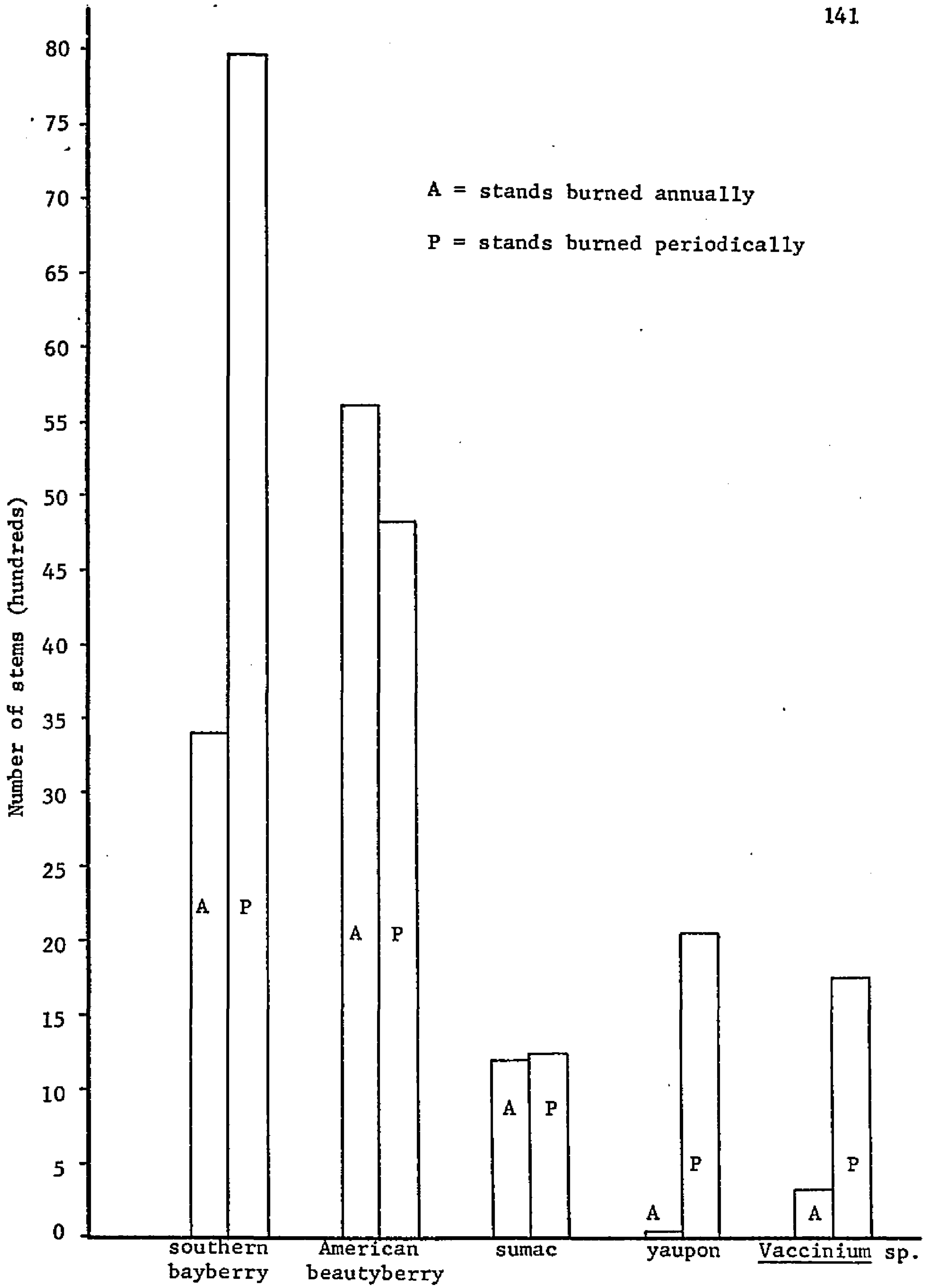

Figure 31. Average stem totals per acre for selected species by burning treatment.

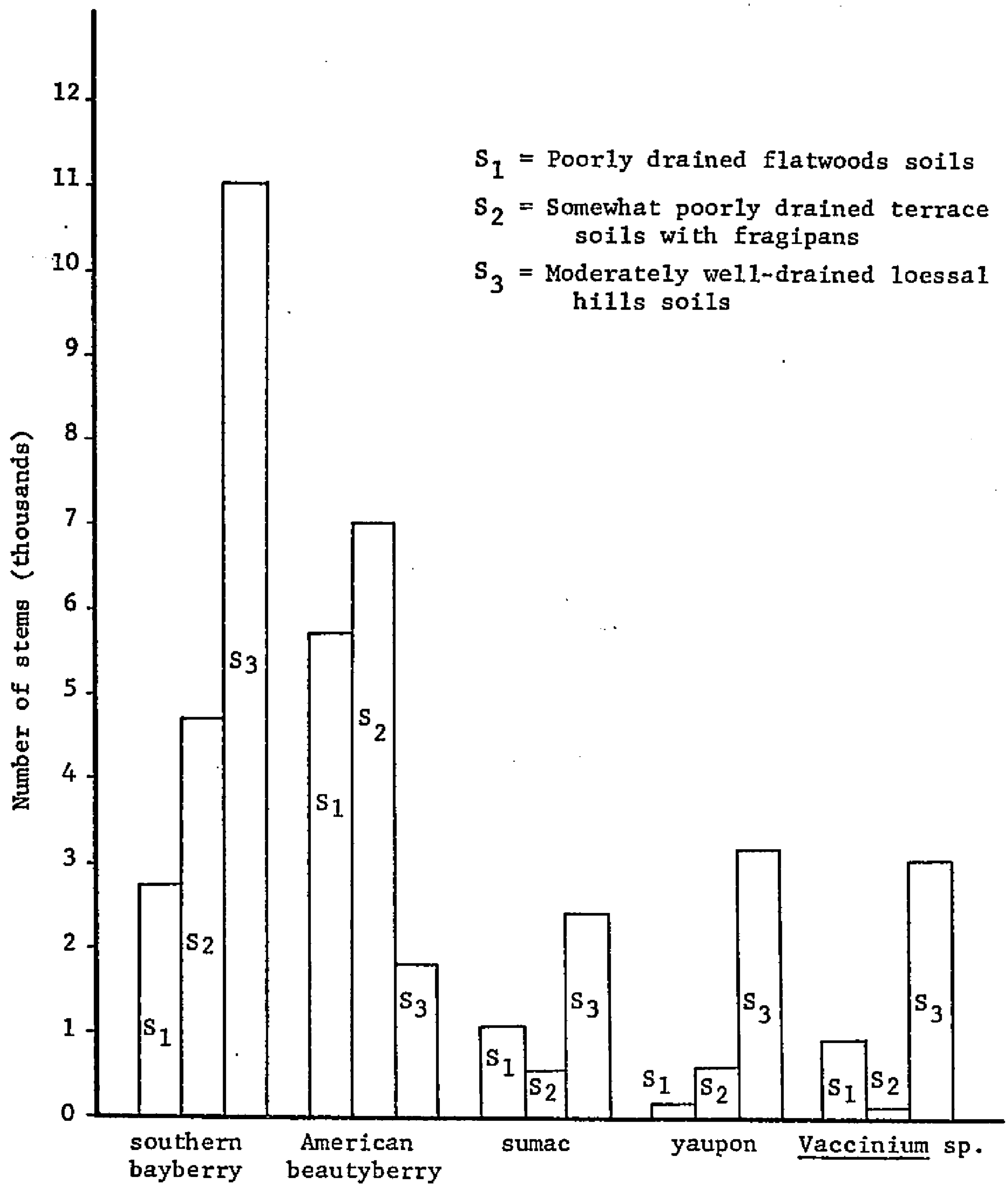

Figure 32. Average stem totals per acre for selected species by soil drainage.

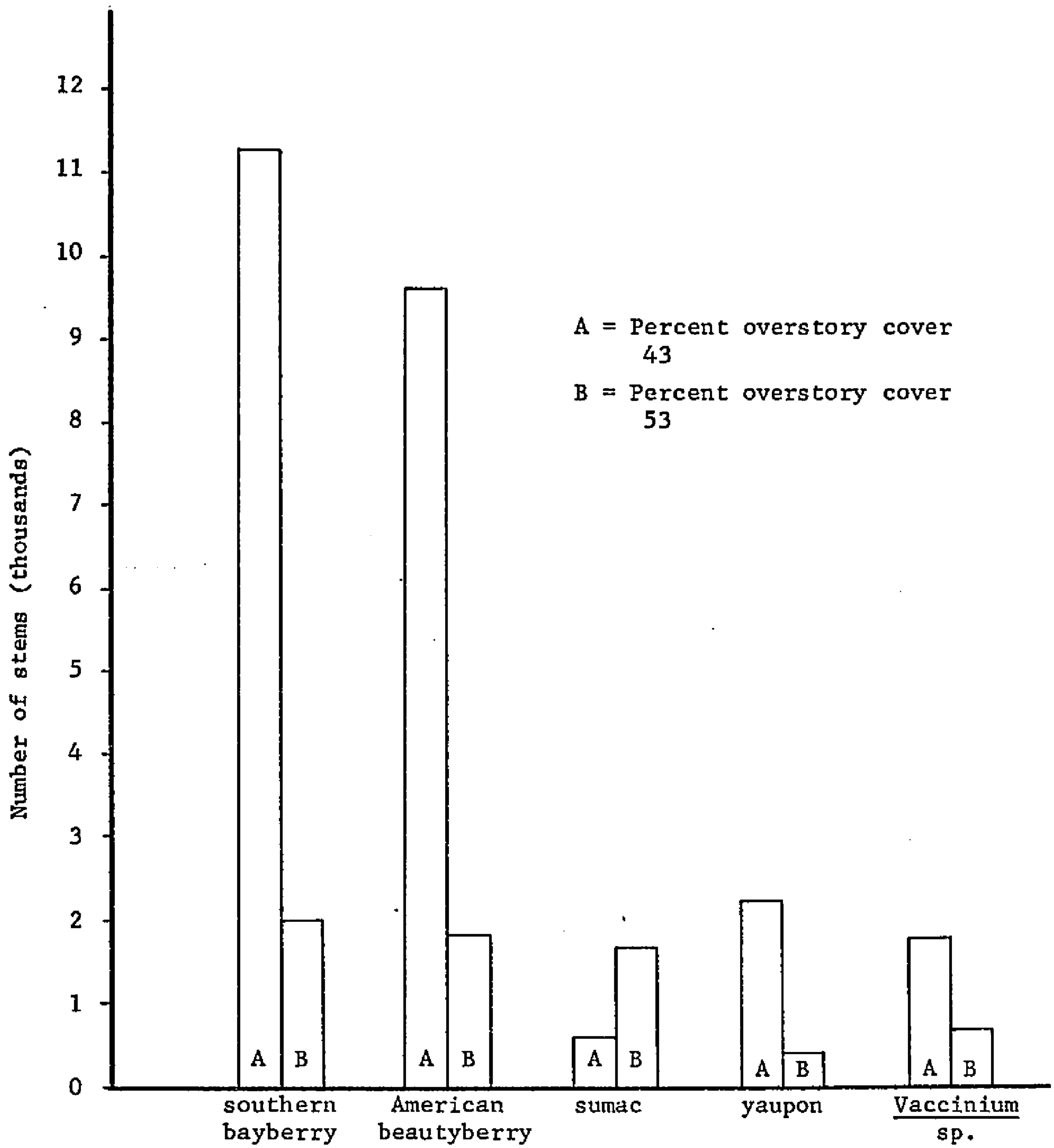

Figure 33. Average stem totals per acre for selected species by overstory cover.

burned stands. There seems little doubt that yaupon and *Vaccinium* sp. rapidly decrease with annual burning.

Study of the stem totals for the species on different soil drainage classes show some trends (Figure 32). American beautyberry showed a preference for the more moist soils, while southern bayberry, which occurred on six of the seven burned stands, was present in much greater numbers on the moderately well-drained loessal hills soil. Sumac also occurred on soils of all the drainage classes, but in larger numbers on the loessal hills soils. Yaupon and *Vaccinium* sp. accounted for a much larger number of stems on the better drained soils than on the poorly drained soils.

One unusual condition is evident in Figure 33. Four of the five species had much larger stem totals where the overstory cover percentage was lower, but sumac, a species characteristic of well exposed areas, showed a much higher occurrence on the stands with the higher overstory cover percentage. This condition may have resulted from the competition of southern bayberry and American beautyberry which dominated the stands with the lower crown density.

Southern bayberry appears to have definite value as an indicator of good control over other undesirable hardwoods. Statistically significant differences between stands burned annually and those burned periodically resulted when southern bayberry was compared. Observation of Figure 32 shows southern bayberry most prevalent in the moderately well-drained soils of the loessal hills. It was often an important, if not dominant, species in both burned and unburned stands. Burning tended to cause profuse sprouting and large numbers of stems grew from a single root collar. Southern bayberry is considered highly resistant to burning and its high frequency of occurrence and stem totals in several stands supported this fact. This species was often a major component of the understory along with American beautyberry.

American beautyberry is fairly common throughout the South. Grelen and Duvall (1966) pointed out that American beautyberry tolerates a wide variety of sites but does best on moist soils under high, open pine canopies. This view was strongly supported by the present study. This species is considered less resistant to fire than southern bayberry but is greater than most understory species. According to the data from the present study, American beautyberry appears to be the more resistant to burning. This species occurred on all the prescribed burned stands with the exception of stand 5, which had little vegetation in the understory. Study of the data and observations indicated American beautyberry as the dominant species on poorly drained flatwoods soils and somewhat poorly drained terrace soils with fragipans and under high crown canopies. Other understory species appeared to have been brought under control (Figure 34). American beautyberry was prominent in the better drained soils of the loessal hills but generally had a lower stem count than sumac.

Sumac has possibilities as an indicator species even though no clear trend was established in the study. Its best use might be in conjunction with southern bayberry on moderately well-drained soils. Sumac was a leading species in the understory vegetation on

Figure 34. Understory dominated by American beautyberry.

moderately well-drained soils under a high canopy. According to the data presented in Figure 32, sumac was an important species on some of the poorly drained soils. This species was missing from two stands with high canopies that were dominated by American beautyberry. Apparently, the fire tolerance of sumac is just below American beautyberry and southern bayberry.

Yaupon and Vaccinium sp. showed significant differences between stands annually burned and periodically burned. These species had very low frequencies of occurrence in the stands on fairly wet soils. Both yaupon and Vaccinium sp. grow best on well-drained soils less acid than those found in most of the stands studied. Only two stands in the moderately well-drained loessal hills were conducive to good growth of these species, and the burning intensity probably affected their distribution. Figures 31, 32, and 33 support the preference of these species for exposed, well-drained soils, and a conservative burning program. Lay (1961) and Grelen and Duvall (1966) noted that hot or frequent fires will eliminate yaupon, but occasional fires of moderate intensity are beneficial in keeping sprout growth within reach of browsing animals. The annual burning program in stand 7 may have killed off the yaupon and severely retarded the Vaccinium sp. Additional study of these species is needed before their value as indicator plants can be assessed.

Vine and Herbaceous Vegetation

Chi-square tests were run for selected herbs and vines (Appendix B). Highly significant differences among stands were found in all calculated tests. These results were anticipated due to the various treatments and conditions in the stands. Study of the frequency of occurrence table reveals some clues which help to explain the distribution of species; however, the presence or absence of some species defy explanation on the basis of the data. Discussion will center mostly on those species which are important as game food or for grazing.

For unexplained reasons, grape (Vitus sp.) occurred most often in areas periodically burned and with mature trees. All three major soil drainage types were represented. The only stand where grape was completely absent from the sample was the one which had been burned annually for 10 years.

Briars (Rubus sp.) followed a definite trend in that fewer occurred in the unburned stands where the midstories and high cover density of the overstory restricted light to the forest floor. Those which did occur were found in disturbed locations or openings that facilitated light reaching the understory area. The burned stands were characterized by a fairly even distribution of briars regardless of soil type, timber age, or burning interval.

Partridge berry was absent from the burned 25- to 35-year-old stands. It occurred most regularly in unburned stands on poorly to somewhat poorly drained soils. The low frequency of occurrence in the unburned young stand was probably due to lower light intensity. A fairly high occurrence of partridge berry in stand 2 (annual burn, mature loblolly pine) was noted. A possible explanation is that the fires each year have been relatively cool due to the size of the stand and its location.

A second exceptional stand was stand 6, a mature, periodically burned stand growing on moderately well-drained loessal soil. The interval between the last two burns was longer than normal and probably permitted the partridge berry to become well established with a good seed supply in the duff at the time of the last fire. Many of these seed were probably unaffected by the fast moving fire.

Partridge pea is a disturbed-area species and is most plentiful along firelines, roadside ditches, and in old fields (Grelen and Duvall 1966). None was recorded on the unburned areas and few stems were found on the burned sites with poorly drained soils. The highest frequency of occurrence was on the moderately well-drained loessal hills soils which had the lowest overstory cover percentage. The lowest frequency of occurrence for partridge pea was on the flatwoods soils.

Yellow jessamine does rather well on most exposed areas, and especially well in full sunlight, on a variety of soil types (Rich 1961). Repeated fires may reduce the vigor or even kill the plant. The distribution in the study area showed a discernible pattern based on our knowledge of its growth habits. The greatest occurrence was on the moderately well-drained soils which had a high exposure to sunlight.

Yellow jessamine was characteristic of most stands but particularly those in the loessal hills. It did not occur in stands 1 and 5 and only once in stand 9. Burning was most likely responsible for its absence in stand 5.

The various species of beggar lice were much more common on burned sites than on unburned areas. These results are supported by most previous studies. Beggar lice was more plentiful on the loessal hills soils than in the flatwoods. Available light might have been influential, but the data and field observations revealed no clear pattern of distribution within the prescribed burned stands.

Greenbriers as a group showed good distribution over the study area. Individual species may have shown a soil preference, but this condition was not detected in the study. The lowest frequency occurred in the 25- to 35-year-old stand which had been burned annually for 10 years. The highest count of stems was found in a mature loblolly pine stand which had never burned.

The highly significant differences among stands for cross vine were due to the low frequency of occurrence or absence from the stands on better drained soils and the better distribution on the poorly drained soils.

Only Panicum sp. was well distributed among the grasses and grass-like plants. High frequencies were recorded in all of the burned stands and about one-half of the subplots in the unburned stands had Panicum sp.

The high occurrence of Paspalum sp. in stand 5 was rather prominent. Fringeleaf paspalum is highly resistant to fire and heavy grazing (Grelen and Duvall 1966). This particular stand had received the most severe burning program (annually for 10 years) and grazing appeared to be rather heavy.

Chi-square tests were made on other herbs (Appendix B). The general trend revealed the lowest frequencies of occurrence in the unburned stands. These results coincide with previous studies of herbaceous vegetation.

SUMMARY AND CONCLUSIONS

The effects of prescribed burning on the understory vegetation in the flatwoods and loessal hills area of southeastern Louisiana were studied. Sites for study were selected on which records of prescribed burning were complete. Unburned stands were located in the vicinity of the burned stands for comparison purposes. Stands had been burned on either an annual or periodic basis.

Ten stands were selected for study in the parishes (counties) of Livingston, St. Helena, and Tangipahoa on six different soil types that were conveniently grouped into three soil drainage classes: poorly drained flatwoods soils, somewhat poorly drained terrace soils with fragipans, and moderately well-drained loessal hills soils.

All stands were divided into two age classes: 25- to 35-year-old trees, and 40- to 50-year-old trees. These stands had crown densities that were grouped into two overstory percentage classes: 43 and 53.

The forest lands in the study area have long been used for grazing as well as for growing timber. All the stands were subjected to grazing, but some areas received more intensive use than others.

All managed stands (prescribed burned) were owned by two large industrial paper companies. Unburned stands were owned by absentee landowners. Information on stand history and cultural treatments was obtained from landowners and foresters responsible for managing the forest land.

Data were obtained from milacre line-belt quadrats for the understory and from one-half square chain quadrats for the midstory and overstory. Understory vegetation was divided into three height classes: less than 3 feet, 3 to 6 feet, and 6 to 8 feet.

A steel-core clothes line 50 links in length was divided into five equal segments. A 1- x 1-inch wood strip 2 links long was grooved across the middle. The strip was moved along the clothes line held taut by two tent pegs. Understory vegetation in this 2- x 50-link quadrat was tallied. Stand data such as dbh, tree height, age and overstory cover were obtained.

Data were transferred to IBM cards for computer analysis. Tabulations of stand data were used in the descriptive interpretations.

Stands had certain characteristics in common when exposed to the same burning program. In stands burned annually one-year-old pine seedlings dominated in number of stems in the understory. The height of the understory was in general less than 3 feet. A relatively small number of shrub and tree species comprised the major part of the understory, but a large number of vine and herbaceous species was common.

Stands burned periodically showed more variation than did the stands burned annually. This was a logical result since the burning intervals for periodic burns ranged up to eight years. An analysis of understory vegetation in these stands showed more variation in height growth than in annually burned stands. A larger number of shrub and tree species, which accounted for a substantial part of the stem totals, was evident in stands burned periodically compared to stands burned annually. A somewhat larger number of frequently occurring vine and herbaceous species was noted in the periodically burned stands.

Unburned stands had much in common even though one stand was much younger than the other two. A multistory effect was evident in the unburned stands that was not present in burned stands. Each of the unburned stands was characterized by a large number of shrub and tree species. Vines, common to all stands, were much larger in size in the unburned stands. Herbaceous vegetation was very limited due to heavy litter accumulations and the limited amount of light reaching the forest floor.

Annually burned stands had an average hardwood stem total only slightly larger than the unburned stands. Stands burned on a periodic basis had nearly twice the number of hardwood stems as the annually burned stands. These data indicated that late winter and early spring burning on an annual basis "kills," as well as "kills back," hardwood species.

Soil drainage had considerable influence as signified by the total number of hardwood stems. Little difference in total stems was observed between poorly drained flatwoods soil and somewhat poorly drained terrace soils with fragipans, but more than twice as many hardwood stems were counted on the moderately well-drained loessal hills soil as on the poorer drained soil.

Light was probably more important in the alteration of the understory than was soil drainage or burning treatment. Tabulations of total stems by overstory cover and correlation analysis of the overstory with the understory demonstrated the effects of light upon the number of stems and number of species in the understory. A decrease in overstory cover from 53 to 43 percent more than doubled the total number of stems in the understory. Hardwood stems increased at the same ratio.

An important side effect of burning was the large amount of bole damage due to burning and/or fusiform rust in a 31-year-old loblolly pine stand that had been annually burned for 10 years. Twenty-five percent of all trees had serious or potentially serious damage. The incident may have been one of poor burning technique, since an intense headfire was used in 1967.

The annually burned stands had as many differences as similarities. The number of vine and herbaceous species was about the same, but the composition and height of the shrub and tree component of the understory varied. The differences among the stands that has been annually burned were either due to soil drainage or the intensive burning program. Stand 5 (25- to 35-year-old loblolly pine stand burned annually for 10 years) had an unusually small number of woody species and total number of stems possibly because of the intensity of burning.

Stands burned periodically showed considerable variation in species composition among stands. The number of shrub and tree species that made up a large proportion of the total stems in stands burned periodically was approximately twice the number of common species that occurred in stands burned annually. The height of the understory was noticeably taller in stands burned periodically. This condition was due in part to the three seasons of growth since the last burn on two of the stands.

Unburned stands had much in common and differed mainly due to age. Each stand had a large number of hardwood species, few, if any, pine seedlings, and a relatively small amount of herbaceous vegetation. Vines differed from burned stands primarily in size and often grew up into the trees on unburned sites.

Study of tabulated stand data and observation in the field made it quite obvious that several factors influenced the understory composition. Some of these factors included soil drainage, stand age, percent of overstory cover, height of the canopy, and the amount of organic litter on the forest floor. When these and other site conditions were exposed to prescribed burning, the results on understory vegetation were very variable. An effort was made to isolate and partition some of the causes for differences through the use of analysis of variance and orthogonal comparisons of selected woody species. Correlation analyses were also computed. Through these techniques certain species were isolated as potential indicators of burning levels.

Five species, southern bayberry, American beautyberry, sumac, yaupon, and *Vaccinium* sp., showed promise as indicator plants of burning levels. Southern bayberry and American beautyberry were the most prominent species on areas that had been burned several times. Each of the five species showed some preference for a given stand condition and soil drainage class. American beautyberry was most prevalent on moist soil under high canopies. Southern bayberry frequented a variety of sites but was especially common on loessal hills soil. Sumac occurred on all drainage classes but in greatest numbers on the loessal hills soils. Yaupon and _Vaccinium_ sp. began to disappear from a stand when burning became intense or on an annual basis. These species would have their greatest value as indicators of burning levels on moderately to well-drained soils. They would be common in the understory under a periodic burning program that would keep the vegetation "killed back" to manageable levels but where little effort is made to eradicate the hardwood understory.

Analysis of vine and herbaceous vegetation revealed high frequencies of occurrence on burned stands and low frequencies of occurrence on unburned stands. A high frequency of occurrence of legumes was found on burned sites, especially on the loessal hills soil. Grape and briars occurred on most burned stands in a somewhat general distribution. Greenbriers as a group showed relatively high frequencies over all the study area. Only _Panicum_ sp. of the grasses had a high frequency of occurrence. Few patterns in the occurrence of herbaceous vegetation developed over all the study sites. Apparently, factors such as surface litter, light, soil drainage, competition from shrub and tree species, and the burning programs combined in such a way to alter the species composition from stand to stand. A small number of vine and herbaceous species generally predominated in a given stand but those same species were not always common in another stand.

On the basis of observation in the field and the data obtained from the present study, the following conclusions and recommendations seem applicable to the flatwoods and loessal hills area of southeastern Louisiana. Recommendations do not apply in stands with trees younger than 25 years.

(1) The widely expressed idea that late winter or early spring prescribed burning will not kill hardwoods, but merely kill them back, appears erroneous. Prescribed burning does result in profuse sprouting which may give the appearance that no rootstocks have been killed. Scrutiny of the data in this study and field observation indicate that annual burning for several years is effective in <u>killing</u> hardwoods; however, there may be concomitant bole damage to the overstory trees as a result of several years of annual burning.

(2) Annual burning can possibly reduce the quality of grazing through damage to certain grasses. Studies have shown that some desirable grasses such as *Andropogon* sp. decline under annual burning; however, other native grasses might increase. A periodic burning program of two- or three-year intervals appears most satisfactory for grazing purposes.

(3) A periodic burning interval of three or four years meets the requirements of most forest land managers who have the primary objective of growing timber but must also sustain other activities such as hunting and grazing. This type of burning program will maintain the fuel supply (pine needles, hardwood leaves, twigs, etc.) at a relatively safe level in fire-prone areas.

(4) The burning interval suggested for timber management is satisfactory in providing good habitat for deer and turkey. In the study area browse plants were seldom out of reach by deer in those stands which had three seasons of growth since the last fire. In areas where quail are present with deer and turkey a two-year burning interval is recommended because legumes are more prevalent under short burning intervals.

(5) If the main objective is the control of the hardwood understory and wildfires are not a problem, a burning interval of eight to ten years will accomplish satisfactory results.

(6) In an area where the forest land manager must contend with hunters, cattlemen, and arsonists, the most appropriate burning interval can seldom be used. "Protective" burning on a short interval or even an annual basis is often essential although there is the danger of bole damage to some trees.

An ecological study of this nature always raises questions that were not anticipated at the beginning. Specifically, the study should have been a cooperative undertaking with a wildlife management person and a soils specialist. The preliminary layout of sample plots could have been used to full advantage to collect much additional information such as the actual nutritive value of the understory for wildlife and cattle and detailed soil data, especially from the standpoint of change, if any, due to prescribed burning.

The tremendous number of stems on the one periodically burned stand in the loessal hills area left some doubt as to the primary causes responsible for the proliferous undergrowth. Additional research in that area is needed to determine the degree of influence of light and soil factors on the undergrowth under both annual and periodic burning.

Available light was considered to be an important variable in every stand studied. The objectives of the study made no provision to differentiate between the amount of overstory cover and the density of the shrub and tree growth in the understory as an influence upon available light reaching the forest floor.

In some instances, competition in the understory itself appeared more influential to the exclusion of certain species than the amount of overstory cover. It is an accepted fact that plant-to-plant competition is a constant activity; however, the question of why certain plants are excluded from the understory even when there apparently is sufficient light is one that needs study. Root competition was without doubt an important variable, but with the exception of soil drainage, which was based upon soil types and their descriptions, no subsurface variable was considered.

There is no exact method of measuring light to the understory for comparative purposes. The changing light angle, the irregularity of the overhead canopy, unpredictable weather conditions, and expensive equipment are but a few of the limitations. Since light appeared to be so important in the present study, a more mechanized study of light conditions might reveal some different results in species composition and stem totals for the study sites.

Soil drainage had a large effect upon the understory vegetation. A more detailed study on the basis of soil types might show statistically significant differences in vegetation composition and number of stems.

In any study where the hardwood vegetation is disturbed by cutting, burning or other means, resprouting from rootstocks takes place. Should an effort be made to determine the number of rootstocks and seedlings or is the total number of stems the more logical statistic to use? Some species are more prolific sprouters than others.

An evaluation of a site for the purpose of grazing could use more quantitative data than presented in the present study. While the frequency of occurrence of herbaceous vegetation is useful, it does not provide enough information to determine carrying capacity for cattle. This type of information would require a separate research project.

No attempt was made, except by observation, to determine the intensity of cattle grazing in the study area. This common practice may or may not have directly affected the conditions in a given stand.

The results of the study should prove useful to the forest land manager even though there are certain shortcomings for a given objective such as grazing. Certainly, the manager interested primarily in growing timber can make use of the data presented. These data should also serve some of the needs of the wildlife manager. Some of the results illustrate how desirable browse species react to different burning regimes.

One of the positive results of the study was the efficiency of the sampling technique. For the understory vegetation two men can proceed on a job with little loss of time, and the equipment needed is minimal. The technique is highly recommended for any similar study.

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APPENDIX A

PLANTS ENCOUNTERED IN THE STUDY

Scientific and common names of shrub and tree species are according to Little (1953). Vine and herbaceous vegetation is based upon Radford, Ahles, and Bell (1968), except for a few common names from Fernald (1950) that are indicated by parentheses.

TREE SPECIES

Scientific name	Common name
Acer rubrum L.	red maple
Carpinus caroliniana Walt.	American hornbeam
Carya glabra (Mill.) Sweet	pignut hickory
Cornus florida L.	flowering dogwood
Crataegus sp.	hawthorn
Crataegus marshallii Eggl.	parsley hawthorn
Diospyros virginiana L.	common persimmon
Ilex opaca Ait.	American holly
Liquidambar styraciflua L.	sweetgum
Magnolia grandiflora L.	southern magnolia
Magnolia virginiana L.	sweetbay
Malus augustifolia (Ait.) Michx.	southern crabapple
Morus rubra L.	red mulberry
Nyssa sylvatica Marsh.	blackgum
Oxydendrum arboreum (L.) DC.	sourwood
Persea borbonia (L.) Spreng.	redbay
Pinus echinata Mill.	shortleaf pine
Pinus glabra Walt.	spruce pine
Pinus taeda L.	loblolly pine
Platanus occidentalis L.	American sycamore
Prunus serotina Ehrh.	black cherry
Quercus alba L.	white oak
Quercus falcata Michx.	southern red oak
Quercus falcata var. pagodaefolia Ell.	cherrybark oak
Quercus laurifolia Michx.	laurel oak
Quercus marilandica Muenchh.	blackjack oak
Quercus nigra L.	water oak
Quercus phellos L.	willow oak
Quercus stellata Wangenh.	post oak
Quercus virginiana Mill.	live oak
Rhus copallina L.	shining sumac
Rhus glabra L.	smooth sumac
Sassafras albidum (Nutt.) Nees.	sassafras
Styrax grandifolia Ait.	bigleaf snowbell
Symplocos tinctoria (L.) L'Her.	common sweetleaf
Ulmus alata Michx.	winged elm
Vaccinium arboreum Marsh.	tree sparkleberry

SHRUB SPECIES

Scientific name	Common name
Callicarpa americana L.	American beautyberry
Euonymus americanus L.	strawberry bush
Ilex decidua Walt.	possumhaw
Ilex vomitoria Ait.	yaupon
Myrica cerifera L.	southern bayberry
Rhododendron canescens (Michx.) Sweet.	wild azalea
Rhus toxicodendron L.	poison oak
Sabal louisiana (Draby) Bomhard	Louisiana palmetto
Sorbus arbutifolia (L.) Heynh.	red chokeberry
Vaccinium sp.	blueberry
Viburnum dentatum L.	(arrow-wood)

VINE SPECIES

Ampelopsis arborea (L.) Koehne	pepper-vine
Anisostichus capreolata (L.) Bureau	cross vine
Berchemia scandens (Hill) K. Koch.	(rattan vine)
Campsis radicans (L.) Seem.	trumpet vine
Gelsemium sempervirens (L.) Ait. f.	yellow jessamine
Lonicera japonica Thunb.	honeysuckle
Lygodium japonicum (Thunb.) Sw.	Japanese climbing fern
Oenothera sp.	evening primrose
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
Rhus radicans L.	poison ivy
Rosa bracteata Wendl.	Macartney rose
Sicyos angulatus L.	bur cucumber
Smilax bona-nox L.	(saw greenbrier)
Smilax glauca Walt.	(cat greenbrier)
Smilax pumila Walt.	(dwarf greenbrier)
Smilax rotundifolia L.	(common greenbrier)
Smilax smallii Morong.	(lanceleaf greenbrier)
Vitus sp.	grape

HERBACEOUS SPECIES

Acalypha virginica L.	three-seeded mercury
Agrimonia rostellata Wallr.	agrimony
Ambrosia sp.	ragweed
Andropogon sp.	
Aristida purpurascens Poir.	three awn
Aster sp.	aster

Scientific name	Common name
Baptisia australis (L.) R. Brown	wild blue indigo
Botrychium dissectum Spreng.	common grapefern
Carduus sp.	thistle
Carex sp.	sedge
Cassia fasciculata Michx.	partridge pea
Centella erecta (L.f.) Fern.	
Centrosema virginianum (L.) Benth.	butterfly pea
Clematis sp.	clematis
Crotalaria angulata Mill.	rattlebox
Crotalaria sagittalis L.	rattlebox (arrow crotalaria)
Crotonopsis linearis Michx.	rushfoil
Cuphea viscosissima Jacq.	waxweed
Cyperus sp.	sedge (green flatsedge)
Desmodium sp.	beggar lice
Dichondra carolinensis Michaux.	dichondra
Diodia teres Walt.	(poorjoe)
Diodia virginiana L.	(buttonweed)
Dracocephalum sp.	obedient plant
Elephantopus tomentosus L.	elephant's foot
Eupatorium sp.	
Eupatorium compositifolium Walt.	(yankee weed)
Eupatorium capillifolium (Lam.) Small	dog fennel
Euphorbia corollata L.	flowering spurge
Galactia sp.	milkpea
Galium sp.	bedstraw
Gnaphalium obtusifolium L.	rabbit tobacco
Hydrangea arborescens L.	hydrangea
Hypericum sp.	St. John's-wort
Hypericum hypericoides (L.) Crantz	St. Andrew's cross
Hyptis alata (Raf.) Shinners	
Jacquemontia tamnifolia (L.) Griseb.	choisy
Juncus sp.	rush
Lespedeza sp.	
Ludwigia peploides var. glabrescens (Kuntze) Shinners	(water primrose)
Lycopus sp.	(bugleweed)
Mentha sp.	mint
Mitchella repens L.	partridge berry
Monarda sp.	(horsemint)
Panicum sp.	
Paspalum sp.	
Phyllanthus caroliniensis Walt.	(leaf-flower)
Pluchea camphorata (L.) DC.	marsh-fleabane
Polygonum pensylvanicum L.	(smartweed)
Polypremum procumbens L.	
Pteridium aquilinum (L.) Kuhn.	bracken
Rhexia sp.	meadow-beauty
Rhynchospora sp.	beak rush

Scientific name	Common name
Rubus sp.	blackberry
Ruellia sp.	ruellia
Rumex acetosella L.	sheep-sorrel
Sabatia angularis (L.) Pursh	rose pink
Sanicula sp.	sanicle; snakeroot
Solanum carolinense L.	nightshade; horsenettle
Solidago sp.	goldenrod
Sonchus asper (L.) Hill	spinty-leaved sow-thistle
Sporobolus sp.	dropseed
Stylosanthes biflora (L.) BSP.	pencil flower
Taraxacum officinale Wiggers	dandelion
Tephrosia sp.	
Tridens flavus (L.) Hitchc.	red top
Trilisa odoratissima (J.F. Gmel.) Cass.	vanilla-plant
Viola sp.	violet

APPENDIX B

FREQUENCY DISTRIBUTION OF VINE AND HERBACEOUS VEGETATION

Table 25. Frequency distribution of vine and herbaceous vegetation

Species[a]	Stand number[b]									
	1	2	3	4	5	6	7	8	9	10
** *Vitus* sp.	22	1	1	4	0	23	8	7	6	29
** *Rubus* sp.	35	32	14	14	41	30	34	39	8	13
** partridge berry	7	30	5	0	0	27	3	40	43	6
** partridge pea	0	11	0	7	3	38	27	0	0	9
** yellow jessamine	0	14	22	14	0	38	49	25	1	12
** beggar lice	7	12	6	25	25	41	47	3	0	15
** greenbriers	8	8	14	2	1	19	11	16	23	9
** cross vine	7	25	0	5	0	1	0	1	11	11
** *Panicum* sp.	48	47	24	42	50	44	47	21	28	44
** *Paspalum* sp.	9	0	0	1	21	1	1	0	0	1
** *Eupatorium* sp.	12	8	3	19	10	30	26	1	1	14
** poison ivy	4	3	8	5	0	18	9	9	26	10
** Virginia creeper	2	3	1	0	0	28	4	0	2	4
** elephant's foot	2	18	3	21	36	30	34	3	3	17
** *Hypericum* sp.	2	0	1	19	25	17	8	2	2	23
** waxweed	49	45	0	1	18	0	0	0	0	1
** goldenrod	0	0	0	8	4	14	2	4	0	16
** rattan vine	2	9	2	3	1	7	8	3	0	4
** bedstraw	0	0	0	0	0	11	29	0	1	6
** dichondra	0	32	0	4	4	3	4	1	0	13
Japanese climbing fern	1	0	0	15	0	1	0	0	0	7
trumpet vine	3	0	0	10	1	1	0	0	0	0
bur cucumber	2	13	0	1	0	1	0	0	0	5
milkpea	0	2	0	5	0	3	16	0	0	0
tephrosia	0	0	0	9	5	2	0	0	0	0
Aster sp.	0	2	0	5	7	0	0	0	0	1
nightshade	5	11	0	1	0	0	0	0	0	2
Andropogon sp.	0	0	0	0	0	9	0	0	0	0
Carex sp.	8	2	6	0	0	6	1	0	0	1

[a]Species by which a ** is found had a calculated chi-square value significant at P = 0.01. Chi-square was not calculated for the remaining number of species due to their small expected values.

[b]Values under each stand number represent the frequency of occurrence for the species listed. Each stand had a total of 50 subplots.

APPENDIX C

SOIL DESCRIPTIONS

CALHOUN SERIES

The Calhoun series is a member of the fine-silty, mixed, thermic family of Typic Glossaqualfs. These soils have gray silt loam A2 horizons that tongue into gray mottled silty clay loam B2t horizons, and light brownish gray mottled silt loam B3 and C horizons.

Typifying Pedon: Calhoun silt loam - pasture
(Colors are for moist soil)

A1 -- 0-3" -- Brown (10YR 4/3) silt loam; moderate fine granular structure; friable; strongly acid; abrupt smooth boundary. (1 to 4 inches thick)

A21g -- 3-12" -- Light brownish gray (10YR 6/2) silt loam; common fine faint light yellowish brown mottles; massive; friable; few short reddish brown concretions; strongly acid; gradual wavy boundary. (6 to 12 inches thick)

A22g -- 12-17" -- Light gray (10YR 7/2) silt loam; common fine distinct yellowish brown mottles; massive; friable; few fine black concretions; very strongly acid; clear irregular boundary. (3 to 8 inches thick)

B2tg -- 17-30" -- Gray (10YR 6/1) light silty clay loam; common fine distinct yellowish brown mottles; weak coarse subangular blocky structure; firm, hard, thin light gray silt coatings around peds in upper few inches; a few silt tongues ½ to 2 inches wide extend through horizon; patchy clay films; common fine brown and black concretions; very strongly acid; gradual wavy boundary. (8 to 20 inches thick)

B3g -- 30-48" -- Light brownish gray (2.5Y 6/2) heavy silt loam; common fine distinct brownish yellow and faint gray mottles; weak coarse subangular blocky structure; firm, hard; few brown and black concretions; strongly acid. (10 to 20 inches thick)

Cg -- 48-72" -- Light brownish gray (2.5Y 6/2) silt loam; common medium distinct brownish yellow (10YR 6/6) mottles; massive; firm, hard; small pockets or veins of light brownish gray silt; few brown concretions; strongly acid.

Type Location: East Baton Rouge Parish, Louisiana; 0.6 mile west of Deerford behind Mose Chapel Church, NW1/4SE1/4 Sec. 2, T. 5 S., R-1 E.

Range in Characteristics: Thickness of the solum ranges from 40 to 70 inches. Calcium magnesium ratios are 1 or more in most horizons. Combined thickness of the A horizons ranges from about 12 to 24 inches.

The A1 or Ap horizon ranges from dark gray through pale brown in hue of 10YR, values of 4 through 6, and chromas of 1 through 3. The A2 horizon ranges from light gray through light brownish gray in hue of 10YR, value of 6 or 7, and chroma of 1 or 2. The A2 horizon is massive or has weak medium subangular blocky structure. Reaction of the A2 horizon is strongly acid or very strongly acid. Tongues of the A2 horizon extend well into the B horizon. The B horizon ranges from gray through light gray in hues of 10YR through 5Y, values of 6 through 7, and chromas of 1 through 2, or to value of 5 and chroma of 1. Mottles are in shades of brown, yellow, and gray. Texture of the B horizon is heavy silt loam or silty clay loam. It contains from 22 to 35 percent clay in its finest part and less than 10 percent sand. The clay content decreases regularly with depth from its maximum in the upper part of the B horizon. The B horizon is strongly acid or very strongly acid but ranges to neutral in the lower part of some pedons. The C horizon has color, texture, and reaction range like the B3 horizon.

Competing Series and their Differentiae: These are the Amagon, Caddo, Crowley, Foley, Fountain, Frost, Guyton, Henry, Lafe, Routon, and Zachary series. Amagon soils lack tonguing of the A2 horizon into the B horizon and contain more than 15 percent sand. Caddo soils contain more than 15 percent sand, and mineralogy is siliceous. Crowley soils have finer texture and an abrupt texture change from the A to the B horizon and lack tonguing to the A2 horizon into the B horizon. Foley soils are more alkaline and have more than 15 percent exchangeable sodium in the lower part of the 3 horizon. Fountain soils have mildly to moderately alkaline B horizons. Frost soils have darker A2 horizons, and B2 horizons that have peds coated with dark gray or black. Guyton soils have more than 10 percent sand and calcium magnesium ratios less than one. Henry soils have fragipans, and the horizon of maximum clay content is below depths of 36 inches. Lafe soils are browner and contain more than 15 percent exchangeable sodium in the B horizon. Routon and Zachary soils lack tonguing of the A2 horizon into the B horizon, and Zachary soils have an abrupt texture change from the A to B horizon.

Setting: Calhoun soils are on nearly level parts and depressions dominantly on Pleistocene terraces. They have formed from loess or other silty material more than 4 feet thick. The climate is warm and humid. Mean annual temperature is 67°F, and average annual rainfall is 58 inches near the type location.

Principal Associated Soils: These are the Calloway, Grenada, Henry, Loring, and Oliver soils all of which have fragipans. In addition, Calloway, Grenada, Loring, and Oliver soils have browner colors.

Drainage and Permeability: Poorly drained. Runoff is slow to very slow, permeability is slow, and internal drainage is very slow.

Use and Vegetation: Mostly in pasture or woodland; some is used for soybeans or other cultivated crops. Forests are loblolly and slash pine, water oak, and sweetgum.

Distribution and Extent: Louisiana, Arkansas, Mississippi, and possibly Tennessee. This series is of large extent.

Series Established: Prairie County, Arkansas, 1906.

Remarks: This soil was formerly classified as a Planosol.

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U. S. A.

LEAF SERIES

The Leaf series is a member of the clayey, mixed, thermic family of Typic Ochraquults. These soils have very dark gray silt loam A horizons and gray clayey Bt horizons.

Typifying Pedon: Leaf silt loam - forested
(Colors are for moist soil)

A1 -- 0-6" -- Very dark gray (10YR 3/1) silt loam; moderate granular structure; friable; many fine roots; very strongly acid; abrupt smooth boundary. 4 to 8 inches thick.

A2g -- 6-9" -- Light brownish gray (2.5Y 6/2) silt loam; many fine distinct light yellowish brown mottles; weak fine and medium granular structure; friable; many fine roots; very strongly acid; clear smooth boundary. 2 to 5 inches thick

B21tg -- 9-28" -- Gray (10YR 6/1) silty clay; common, medium prominent red (10R 4/6) and common medium distinct yellowish brown (10YR 5/6) mottles; moderate fine and medium angular blocky structure; firm, plastic; common fine roots; clay films on ped faces; very strongly acid; gradual smooth boundary. 16 to 25 inches thick.

B22tg -- 28-40" -- Light brownish gray (2.5Y 6/2) silty clay; common medium prominent red (10R 4/6) and common medium distinct yellowish brown (10YR 5/6) mottles; moderate medium angular blocky structure; firm, plastic; few fine roots; clay films on ped faces; very strongly acid; gradual smooth boundary. 8 to 16 inches thick.

B3g -- 40-72"+ -- Gray (10YR 6/1) silty clay; many medium distinct strong brown (7.5YR 5/6) and yellowish brown (10YR 5/6) mottles; and few fine prominent red mottles; weak medium angular blocky structure; firm, plastic; very strongly acid.

Type Location: Jackson County, Mississippi; 2 miles northeast of Escatawpa, Mississippi, SE¼, NW¼, Sec. 5, T 7 S, R 5 W.

Range in Characteristics: Leaf soils are usually moist and are saturated with water at some season. Base saturation by sum of cations is less than 35 percent throughout. Mean annual soil temperature ranges from 59°F to 72°F. Solum thickness is usually more than 60 inches. Color of the A1 horizon is in hue of 10YR and ranges in value from 3 through 4 and chroma of 1 and 2. The A2 horizon is in hue of 10YR and 2.5Y, ranges in value from 5 through 6 and chroma of 1 and 2. Texture of the A1 and A2 horizon is silt loam, very fine sandy loam, fine sandy loam and loam. The Bt horizon ranges in hue from 10YR to 2.5Y, in value from 6 through 7 and in chroma of 2 or less, or in values of 4 through 5 and chromas of less than 2. Some pedons have gray colors in hue of 5Y. Over 60 percent of the mass between the Ap or A1 and to a depth of 30 inches has the above colors. Few to many mottles in shades of red, yellow and brown are generally present throughout the B horizon. Texture of the B2t horizon is a heavy silty clay loam, heavy clay loam, silty clay or clay. Some pedons have a thin silt loam or loam B1t horizon, but the weighted average clay content of the upper 20 inches of the Bt horizon is between 35 and 60 percent. Silt content is more than 30 percent throughout. Some pedons have small pockets or thin streaks of silt between ped faces. Reaction of the soil ranges from strongly to very strongly acid.

Competing Series and Their Differentiae: These are the Angie, Atmore, Bladen, Coxville, Dunbar, Elkton, Forestdale, Grady, Lenoir, Myatt, and Wahee series. The Angie soils have yellowish brown B horizons and have gray mottles in the upper 30 inches of the solum. The Atmore soils have fragipans and have more than 5 percent nonindurated plinthite within 60 inches from the surface. Bladen soils have less than 30 percent silt in the upper 20 inches of the Bt horizon. Coxville and Grady soils have kaolinite as the dominant clay mineral and have less than 30 percent silt throughout. Dunbar and Wahee soils are less gray in the upper Bt horizon and have kaolinite as the dominant clay mineral. Elkton soils have mean annual temperatures of less than 59°F. Forestdale soils have more than 35 percent base saturation by sum of cations at 50 inches below the top of the argillic horizon. Lenoir soils have higher chromas and have less than 60 percent of the mass between the Ap and 30 inches dominantly gray colors. Myatt soils have 18 to 35 percent clay in the upper 20 inches of the Bt horizon.

Setting: The Leaf soils occur on nearly level to gentle slopes of the Coastal Plain with surface gradients of less than 3 percent. The regolith is stream and marine deposits of clayey sediments. The climate is warm and humid. The average January temperature is 50.0°F, average July temperature is 81.0°F and average annual precipitation is 57.0 inches near the type location.

Principal Associated Soils: These are the Angie, Atmore, and Myatt soils listed among the competing series and the Mashulaville, Sawyer, Stough, and Weston soils. Mashulaville and Stough soils have fragipans. Sawyer soils are yellowish brown and have 18 to 30 percent clay in the upper Bt horizon over clayey lower Bt horizon. Weston soils have 10 to 18 percent clay in the upper 20 inches of the Bt horizon.

Drainage and Permeability: Poorly drained. Runoff is slow to very slow. Permeability is slow to very slow.

Use and Vegetation: Most of the Leaf soils is in forest. Some of the soil is used for growing corn and small grains. Principal vegetation of forest areas is water oak, sweetgum, black gum, few scattered loblolly pine, and white oak.

Distribution and Extent: Southern Coastal Plain in the states of Alabama, Arkansas, Florida, Georgia, Mississippi, North Carolina, and South Carolina. The series is of moderate extent.

Series Established: Forrest County, Mississippi, 1911.

Remarks: The series was formerly classified in the Planosol great soil group. Further studies are needed to solve the distinction between the Leaf and Roanoke series.

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OLIVIER SERIES

The soils of the Olivier series are classified as Aquic Fragiudalfs, members of a fine silty, mixed, thermic family. They have yellowish brown mottled heavy silt loam to light silty clay loam Bt horizons with evident clay films overlying silt loam fragipan horizons. A single clay maximum occurs above the fragipan horizon.

Typifying Profile: Cultivated field
(Munsell colors for moist soil unless otherwise indicated.)

Ap -- 0-6" -- Grayish brown (10YR 5/2) silt loam; weak medium granular structure; friable; common soft black and brown concretions; medium acid; abrupt smooth boundary.

A2 -- 6-9" -- Yellowish brown (10YR 5/4) silt loam; few fine faint grayish brown mottles; massive to weak medium and coarse granular and coarse granular structure; friable; common soft brown and black concretions; medium acid; clear smooth boundary.

B21t -- 9-15" -- Yellowish brown (10YR 5/4) heavy silt loam; moderate medium subangular blocky structure; friable; peds have many thin patchy brown (10YR 5/3, 6/2 dry) silt coatings; common yellowish red to black soft Fe-Mn segregations; strongly acid; clear wavy boundary. Patchy clay films.

B22t -- 15-22" -- Yellowish brown (10YR 5/6) heavy silt loam; many grayish brown (10YR 5/2) and brown (10YR 5/3) mottlings and thin silt coatings; moderate fine and medium prismatic structure; firm; distinct patchy clay films on vertical and horizontal surfaces; common fine red to black Fe-Mn segregations; very strongly acid; gradual wavy boundary.

B23t -- 22-30" -- Yellowish brown (10YR 5/4) heavy silt loam; common fine distinct grayish brown (10YR 5/2) and brown (10YR 5/3) mottles; strong fine and medium prismatic structure; firm; distinct patchy clay films on vertical and horizontal surfaces; prisms have thin grayish brown (10YR 5/2) silt coatings; many fine pores; common red to black Fe-Mn segregations; very strongly acid; clear irregular boundary.

Btx & A'2x -- 30-37" -- Yellowish brown (10YR 5/4) medium silt loam; common fine distinct grayish brown (10YR 5/2) and brown (10YR 5/3) mottles; strong medium and coarse prismatic structure; firm; common small vertical veins of grayish brown (10YR 5/2) silt between prisms; a few patchy clay films; many fine pores; common yellowish red to black Fe-Mn segregations; very strongly acid; gradual smooth boundary.

Btx & A'2x -- 37-52" -- Yellowish brown (10YR 5/4) medium silt loam; common fine distinct grayish brown (10YR 5/2) light gray (10YR 7/2) and yellowish brown (10YR 5/6) mottles; strong medium and coarse prismatic structure; firm; vertical and horizontal silt veins of light brownish gray (10YR 6/2) between prisms; many fine pores; common soft brown and black Fe-Mn segregations; strongly acid; diffuse wavy boundary.

B'3x -- 52-64" -- Yellowish brown (10YR 5/6) medium silt loam; weak medium and coarse prismatic structure; firm; thin silt coatings of light brownish gray (10YR 6/2) between prisms; many fine pores; strongly acid.

Type Location: East Baton Rouge Parish, Louisiana. Site of profile described. One mile west of Plains, 100 feet north of Plains - Port Hudson Highway. Southeast part of northern segment of Sec. 61, T 4 S, R 1 W.

Range in Characteristics: Solum thickness ranges from about 4 to 6 feet. Texture of the A1 or Ap horizons range from silt to silt loam. Ap or A3 horizons range from 5/ to 6/ in value and /2 to /4 in chroma in hues of 10YR. Finest texture occurs in the B2t horizons and ranges from heavy silt loam to medium silty clay loam and clay content decreases regularly with depth. Sand content is less than 10 percent and dominated by the very fine sand fraction. Color of the B2t horizons range from 4/ to 6/ in value and /3 to /6 in chroma in hues of 10YR or chroma may range to /2 if below the upper 10 inches. The B2t may be free of mottles in the upper part but contains mottles of dary grayish brown (10YR 4/2) to light gray (10YR 7/1) within the top 10 inches. Mottles of higher chroma may occur. Thickness of the B2t ranges from 8 to 24 inches. B'x and A'2x horizons occur below the B2t. The A'2x portions are grayish brown (10YR 5/2), brown (10YR 5/3), light gray (10YR 7/2) or pale brown (10YR 6/3) occurring as coatings of silt or light silt loam around prisms or in vertical veins. B'x portions are 4/ to 6/ in value and /3 to /6 in chroma in hues of 10YR or may range to chroma of /2. The B horizon ranges from strongly acid to very strongly acid.

Competing Series and their Differentiae: These include the Calloway and Grenada soils that have bisequal profiles with double clay maxima; the Bude and Hatchie soils also have bisequal profiles as well as higher sand content in some part of the solum; the Loring soils that are similar in clay distribution but lacking low chroma mottles in the upper B horizon all being in the same Great Group. The Stough soils have higher sand content and lower base saturation. *Pride soils are in the same family but have higher sand content.

Principal Associated Soils: These include extensive soils such as the well drained Memphis, the moderately well drained Loring, and the poorly drained Calhoun, all of which are acid. Associated soils of minor extent are the *Deerford, Lafe, Foley, and *Bonn which have natric horizons. Grenada, Calloway, and Henry soils are also possible landscape associates.

Setting: Olivier soils occur on slopes of about ½ to 3 percent in the uplands or on terraces usually of low relief. The parent materials are Pleistocene deposits of uncertain origin that have very low sand content and many characteristics of loess. The mean annual temperature at the type location is 67.5°F and average annual rainfall 54.5 inches.

Drainage and Permeability: Somewhat poorly drained. Runoff slow to medium. Permeability moderately slow in upper part and slow in the fragipan.

Use of Vegetation: Cultivated crops such as cotton, corn, truck crops, small grain. A considerable amount is used for pasture and woodland. Native vegetation was mixed hardwoods.

Distribution and Extent: South Louisiana, possibly southern Mississippi or other areas where the associated soils occur. They are of moderate extent.

Series Established: Iberia Parish, Louisiana, 1911.

Remarks: The proposed concept of Olivier is within the range of earlier usage in Louisiana. However, some of the soils mapped Olivier in the past are well within the proposed concept of Calloway.

Laboratory data for type location is in the Lincoln Soil Survey Laboratory Report for Selected Samples (1961) from East Baton Rouge Parish, Louisiana -- Profile S61-La-17-1 under the name of Calloway silt loam.

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PROVIDENCE SERIES

The Providence series is a member of the fine-silty, mixed, thermic family of Typic Fragiudalfs. Typically, they have gray silt loam A horizons, strong brown silty clay loam Bt horizons, and yellow, gray and red compact and brittle loamy fragipans.

Typifying Pedon: Providence silt loam - forested
(Colors are for moist soil.)

A1 -- 0-3" -- Dark gray (10YR 4/1) silt loam; weak fine granular structure; very friable; many fine roots; strongly acid; clear smooth boundary. (1 to 5 inches thick.)

A2 -- 3-7" -- Grayish brown (10YR 5/2) silt loam; weak medium granular structure; very friable; common fine roots; very strongly acid; clear smooth boundary. (4 to 7 inches thick.)

B1 -- 7-10" -- Strong brown (7.5yr 5/6) silt loam; weak fine subangular blocky structure; friable, slightly sticky; few root channels filled with gray silt loam; common fine roots; strongly acid; clear wavy boundary. (3 to 6 inches thick.)

B21t -- 10-14" -- Strong brown (7.5YR 5/6) heavy silt loam; weak fine subangular blocky structure; friable, slightly sticky; common fine roots; thin patchy clay films on peds, clay films evident in pores and root channels; strongly acid; clear smooth boundary. (4 to 6 inches thick.)

B22t -- 14-23" -- Strong brown (7.5YR 5/6) silty clay loam; moderate fine and medium subangular blocky structure; friable; slightly sticky; few fine roots; thin patchy clay films on ped faces; evident clay films in pores and root channels; common brown coatings on ped faces in lower part; strongly acid; clear irregular boundary. (6 to 14 inches thick.)

Bx1 -- 23-28" -- Strong brown (7.5YR 5/6) heavy silt loam; common medium distinct light yellowish brown and light brownish gray mottles; moderate medium subangular blocky structure; firm, compact and brittle; many fine pores; few thin clay films on peds; common black concretions; strongly acid; clear wavy boundary. (4 to 10 inches thick.)

IIBx2 -- 28-38" -- Mottled yellow (10YR 7/6), light brownish gray (2.5Y 6/2) and yellowish red (5YR 4/6) silt loam containing noticeable sand; moderate fine and medium subangular and angular blocky structure arranged in large prisms; firm, compact and brittle; many fine pores; light brownish gray silt between prisms; patchy clay films on peds and lining pores and cracks; strongly acid; clear wavy boundary. (4 to 12 inches thick.)

IIBx3 -- 38-53" -- Yellowish red (5YR 4/6) loam, few fine distinct light brownish gray mottles; weak coarse subangular and angular blocky structure arranged in large prisms; firm, compact and brittle; few fine pores; light brownish gray silt coating on a few ped faces and in cracks between prisms; patchy clay films on peds and lining pores and cracks; strongly acid; gradual wavy boundary. (0 to 20 inches thick.)

IIB23t -- 53-60" -- Red (2.5YR 4/6) sandy loam; few fine distinct light gray mottles; weak coarse subangular blocky structure; friable; sand grains coated and bridged with clay; strongly acid.

Type Location: Lincoln County, Mississippi; 10 miles northeast of Brookhaven, 145 feet west and 72 feet north of the SE corner of SW¼ SE¼, Sec. 10, T. 7 N., R. 9 E.

Range in Characteristics: The Providence soils are usually moist; in most years, they are not dry for as much as 60 consecutive days in all parts nor for 90 cumulative days in some horizon between 7 and 20 inches. Mean annual soil temperature is more than 59°F. Depth to the fragipan ranges from 18 to 38 inches. Base saturation by sum of cations is more than 35 percent at 30 inches below the top of the fragipan. Reaction of soil ranges from medium to very strongly acid, except in areas that have been limed. The A1 horizon has hue of 10YR or 2.5Y, value of 2 through 4, and chroma of 1 through 3. The A2 horizon has hue of 10YR or 2.5Y, value of 4 through 6, and chroma of 2 through 4. Where the soil is cultivated, the Ap horizon is the same color as the A2 horizon. The B1 horizon has hue of 7.5YR or 10YR, value of 4 or 5, and chroma of 4 through 8. The B1 horizon is silt loam or silty clay loam. The Bt horizon has hue of 5YR through 10YR, value of 4 or 5, and chroma of 4 through 6. It is silt loam or silty clay loam. The argillic horizon usually contains 22 to 30 percent clay and ranges from 18 to 35 percent clay and 5 to 15 percent sand. The fragipan has yellowish red to yellowish brown matrices that are mottled gray, brown, and red, or they are mottled yellow, brown, gray and red. The upper part of the fragipan is light silty clay loam or silt loam that contains evident amounts of sand. The lower part is clay loam, sandy clay loam or sandy loam. It ranges from firm to very firm. The IIB23t horizon ranges in color from red to gray. Texture of the IIBt horizon ranges from sandy loam to clay.

Competing Series and their Differentiae: These are the Bude, Lax, Leverett, Loring, Olivier, Ora, and Paden series. The Bude soils have 2 layers that have clay maxima and a horizon between the top of the fragipan and the surface that has mottles of 2 or lower chroma. Lax soils have less than 35 percent base saturation at 30 inches below the top of the fragipan. Leverett soils have 10 to 18 percent clay in the Bt horizon. Loring soils have sola 48 or more inches thick and contain less than 15 percent sand throughout. Olivier soils have mottles of 2 or lower chroma in the upper 10 inches of the Bt horizon. Ora soils have more than 15 percent fine and coarser sand in the Bt horizon. Paden soils have two layers that have clay maxima and a horizon between the top of the fragipan and the surface that has few or no clay films.

Setting: The Providence soils are on nearly level to moderately steep topography. Slopes range from 1 to 15 percent. The regolith is a mantle of loess about 2 feet thick and sandy to clayey coastal plain sediments. The climate is warm and humid. The average January temperature is 50°F, average July temperature is 82°F, the mean annual temperature is about 67°F, and the mean annual precipitation is 57.0 inches near the type location.

Principal Associated Soils: These are the Loring and Paden soils listed as competing series and the Lexington, Ruston and Saffell soils. The Lexington soils lack fragipans. Ruston soils lack fragipans and have more than 15 percent fine and coarser sand in the upper 20 inches of the Bt horizon. Saffell soils lack fragipans and have more than 35 percent gravel in the Bt horizon.

Drainage and Permeability: Moderately well drained. Runoff is slow to medium. Permeability is moderate in the upper part of the B horizon and moderately slow in the fragipan.

Use and Vegetation: Most of the Providence soils are used for growing corn, cotton, small grains, annual legumes, truck crops, and orchards. Some of the soil is used for pasture. Native vegetation is forest of oaks, gum, pines, hickory, beech, and elm.

Distribution and Extent: Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. The series is of moderate extent.

Series Established: Calloway County, Kentucky, 1938.

Remarks: The Providence series was formerly classified in the Gray-Brown Podzolic great soil group. The series as now defined will include that part of the soil formerly included in the Dulac series that have base saturation by sum of cations of more than 35 percent at 30 inches below the top of the fragipan.

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SPRINGFIELD SERIES

The Springfield series is a member of the fine, mixed, thermic family of Aeric Albaqualfs. These soils have light colored A2 horizons and an abrupt textural change between the A horizon and the B horizon. The B horizon is brownish-gray or grayish-brown silty clay mottled reddish-brown or yellowish-red in the upper part and grades to yellowish-brown silt loam or light silty clay loam with increasing depth.

Typifying Profile: Springfield silt loam - woodland
(Colors are for moist soil unless otherwise stated.)

A1 -- 0-3" -- Grayish-brown (10YR 5/2) silt loam, common fine faint dark yellowish-brown (10YR 4/4) mottles; weak very fine granular structure; friable; medium acid; clear smooth boundary.

A21g -- 3-10" -- Light brownish-gray (10YR 6/2) silt loam, common fine distinct yellowish-brown (10YR 5/6) mottles; weak fine subangular blocky structure; friable; many pores; very strongly acid; clear smooth boundary.

A22g - 10-13" -- Light gray (10YR 7/2) silt loam; a few peds of yellowish-brown (10YR 5/6) silt loam or slightly finer; weak coarse subangular blocky structure; friable; many pores; very strongly acid; abrupt wavy boundary.

B21tg - 13-20" -- Grayish-brown (2.5Y 5/2) grading to grayish-brown (2.5Y 5/3) with depth, silty clay, common fine distinct reddish-brown (5YR 4/4) mottles; weak medium subangular blocky structure; very firm; distinct clay films; upper 1 inch of horizon has thin (1 mm) distinct silty ped coatings; a few tongues of A2 horizon 1 to 2 inches wide extend 6 to 8 inches into this horizon; very strongly acid; gradual smooth boundary.

B22t -- 20-31" -- Yellowish-brown (10YR 5/4) heavy silty clay loam, common fine faint light brownish-gray (10YR 6/2) and yellowish-brown (10YR 5/6) mottles; moderate coarse subangular blocky structure arranged in weak fine prisms; very firm; few patchy dark gray (10YR 4/1) coatings; a few Fe-Mn streaks; slightly acid; gradual smooth boundary.

B3 -- 31-44"+ -- Yellowish-brown (10YR 5/4) light silty clay loam, common fine faint light brownish-gray (10YR 6/2) and yellowish-brown (10YR 5/6) mottles; weak coarse subangular blocky structure; firm; mildly alkaline.

Type Location: Livingston Parish, Louisiana; 1/2 mile southwest of Frost, 100 feet north of Louisiana Highway 42, NW¼ Section 31, R 5 E, T 7 S.

Range in Characteristics: Solum thickness ranges from about 30 to 50 inches. The A1 horizon ranges from 10YR to 2.5Y in hue, from 3 to 5 in value, and from 1 to 3 in chroma. The A21g horizon ranges from 10YR to 2.5Y in hue, and from 6 to 7 in value; it is typically of 2 chroma but ranges from 1 to 3. The A22g horizon ranges from 10YR to 2.5Y in hue, from 5 to 7 in value, and from 1 to 2 in chroma. The B21 horizon ranges from 10YR to 2.5Y in hue, from 5 to 6 in value, and is dominantly of 2 chroma; it contains dark reddish-brown, yellowish-red, or reddish-brown mottles. Textures are clay or silty clay. Reaction of the B21 horizon ranges from medium to very strongly acid. The B22 and B3 horizons have 10YR hue, and values range from 4 to 5 and chromas from 4 to 6; they contain mottles of light gray or brownish-gray. The C horizon has colors of the same range as the B3. Texture below the B21 horizon is progressively lighter and silt loam or light silty clay loam is at depths of 30 to 40 inches and below. Reaction ranges from medium acid to mildly alkaline in the B3 and C horizons.

Competing Series and their Differentiae: The Wrightsville and Crowley soils of the same great group and Axtell soils of the same subgroup have low chroma and finer texture in the lower sola. The Calhoun soils of the same suborder have silty clay loam B horizons. Hillemann soils have high exchangeable sodium and lack the abrupt textural change between the A and B horizons. Acadia soils lack an abrupt textural change from the A to B horizons and have finer textured C horizons. Patoutville soils have A horizons of lower color values and B21 horizons dominated by higher chromas and darker ped coatings. Forestdale soils lack the abrupt textural change between the A and B horizons, and they have lower chroma in the lower part of the B horizon.

Setting: These soils are on nearly level uplands or terraces in areas of very low relief. Slopes range from about 1/2 to 2 percent. The parent materials are late Pleistocene deposits of uncertain origin; they are very low in sand and have many characteristics of loess. The average temperature at the type location is 52°F in January and 81°F in July. Average annual precipitation is 58 inches.

Principal Associated Soils: These are the poorly drained Calhoun soils and the somewhat poorly drained Olivier soils.

Drainage and Permeability: Poorly drained marginal to somewhat poorly drained; runoff is slow; permeability is slow.

Use and Vegetation: Forested, dominantly to Loblolly pine and some hardwoods. A few areas have been cleared for pasture.

Distribution and Extent: The soil is of small total extent but it is in large areas that are important locally.

Series Established: Livingston Parish, Louisiana, 1931.

Remarks: The Patoutville and Acadia are closely competing series, both of which are undergoing revision at this time.

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STOUGH SERIES

The Stough series are members of a coarse-loamy, siliceous, thermic family of Aquic Fragiudults. These soils have moderately coarse to medium textured, light colored surface horizons, upper subsoils of similar texture, and a compact lower subsoil (fragipan).

Typifying Pedon: Stough fine sandy loam
(Colors are for moist soil.)

A1 -- 0-4" -- Very dark gray (10YR 3/1) fine sandy loam; weak fine and medium granular structure; friable; common fine roots; few root and worm holes filled with material from A2 in lower part of horizon; few fine and medium black and brown concretions; strongly acid; clear smooth boundary. 1 to 5 inches thick.

A2 - 4-9" -- Mottled yellowish brown (10YR 5/4) and dark grayish brown (10YR 4/2) loam; mottles are many, fine, distinct, and appear to be due to mixing by worms; weak, fine and medium granular and weak, fine and medium subangular blocky structure; friable; common fine roots; few fine and medium brown and black concretions; strongly acid; clear smooth boundary. 3 to 7 inches thick.

B21t -- 9-17" -- Mottled light yellowish brown (10YR 6/4), brownish yellow (10YR 6/6) and light brownish gray (10YR 6/2) loam; weak, fine and medium subangular blocky structure; friable; few fine roots; clay bridges between sand grains; few discontinuous clay films on some peds; common fine and medium brown and black concretions; strongly acid; clear smooth boundary. 6 to 10 inches thick.

Bx1 -- 17-24" -- Mottled yellow (2.5Y 7/6), yellowish brown (10YR 5/6) and light gray (10YR 7/1) loam; very coarse prisms separated by gray ¼ to ½ inch wide tongues of loamy sand extend downward through the remainder of the solum; material in prisms has weak fine and medium subangular blocky structure; slightly hard, friable; slightly compact and brittle; few fine roots; patchy clay films on peds and in pores; clay bridges between sand grains; common fine and medium and few coarse black and brown concretions; strongly acid; clear smooth boundary. 6 to 12 inches thick.

Bx2 -- 24-34" -- Mottled light yellowish brown (2.5Y 6/4), light gray (2.5Y 7/2) and yellow (10YR 7/6) fine sandy loam; weak, medium and coarse subangular and angular blocky structure; slightly hard, friable, slightly compact and brittle; common fine pores; vertical tongues less than 1 inch wide of pale yellow (5Y 7/3) loamy sand; common, fine and medium brown and black concretions; strongly acid; gradual smooth boundary. 8 to 12 inches thick.

Bx3 -- 34-50" -- Mottled light gray (2.5Y 7/2), yellowish brown (10YR 5/6) fine sandy loam; weak; coarse and medium subangular blocky structure; slightly hard, friable, compact and brittle; common fine pores; few tongues less than 1 inch wide of yellow (5Y 7/3) loamy sand; few fine brown and black concretions; strongly acid; gradual smooth boundary. 8 to 15 inches thick.

C -- 50-65" -- Mottled strong brown (7.5Y 5/8), light gray to gray (10YR 6/1) and brownish yellow (10YR 6/6) fine sandy loam; structureless, massive; friable; few tongues of light gray to gray (N 6/) sandy clay loam and few tongues of yellow (5Y 7/3) loamy sand; strongly acid.

Type Location: Clarke County, Mississippi; ½ mile west of Enterprise, 300 feet south of NW corner of SW¼ SW¼ Sec. 23 T 4 N, R 14 E.

Range in Characteristics: Textures of the A horizons are fine sandy loam, loam and silt loam. The A1 horizon has hues of 10YR or yellower and values of 2 through 4 and chromas of 1 and 2. The A2 horizon has 10YR or yellower hues and values of 4 to 6 and chromas of 2 to 4. In cultivated or heavily grazed areas, the A1 and A2 horizons are mixed to form an Ap horizon having a texture range similar to the A2 horizon and colors that range from light brownish gray (10YR 6/2) to dark grayish brown (10YR 4/2). The B2t horizon has 10YR or yellower hues and ranges from yellowish brown to pale yellow and has few to common mottles of 2 chroma within 10 inches of the top of the horizon. The texture ranges from sandy loam to silt loam; less than 18 percent clay, more than 15 percent silt and more than 15 percent sand coarser than very fine sand. The Bx horizons (fragipan) have hues of 10YR and 2.5Y and are generally distinctly mottled with shades of gray, yellow, and brown. The fragipan horizons have a range of texture similar to the B2t horizon. Fragipan expression is weak.

Competing Series and their Differentiae: These include the Quitman, Pheba, Bude, Hatchie, Lynchburg, and Hasty soils. Quitman soils in the same subgroup as Stough have a more clayey (18 to 35 percent) control section. Pheba soils contain more silt and clay, and are bisequel. Bude and Hatchie soils also contain more silt and clay, are bisequel, and have base saturation that exceeds 35 percent within 30 inches from the top of the fragipan. Lynchburg and Hasty soils have more clay in their control sections and lack fragipans.

Setting: The Stough soils occur on nearly level to gently sloping marine and fluvial terraces and broad nearly level to gently sloping Coastal Plain uplands. Slopes range from 0 to 5 percent, but most of the soil has slopes between 1 and 3 percent. The regolith is marine or fluvatile deposits that range in texture from sands to clays.

Principal Associated Soils: These include the Prentiss, Cahaba, and McLaurin soils which occupy the better drained higher positions in the landscape. Myatt, Weston and Mashulaville occupy the poorer drained lower positions.

Drainage and Permeability: Somewhat poorly drained; runoff is slow. Permeability is moderate in the upper part of the solum but moderately slow in the fragipan.

Use and Vegetation: Used chiefly for pasture and forest. Some areas have been cleared and where drained are used for cotton, corn, small grains, and truck crops. Forested areas are chiefly in mixed hardwoods and some pines.

Distribution and Extent: Coastal Plain sections of Alabama, Arkansas, Louisiana, Mississippi, Florida, North Carolina, South Carolina, and possibly Virginia.

Series Established: Lower East Saline SCD, Drew County, Arkansas, 1939.

Remarks: This revision restricts the Stough series to soils with a coarse-loamy control section. The Quitman series is being proposed for those soils with a fine-loamy control section formerly mapped in the Stough series. This proposal conforms to recommendations outlined in the report of "Classification of Soils in the Gulf Coastal Plain of the Southern States, November 1964." The Stough soils were formerly classified as somewhat poorly drained Planosola with fragipan.

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VITA

Hershel Clayton Reeves was born on August 5, 1928, in Alva (Harlan County), Kentucky. He completed his public education in eastern Kentucky and graduated from Rockholds High School in 1946. He entered Cumberland Junior College in 1947 and graduated in 1949.

He worked at various jobs including logging, timber cutting, sawmilling and punch-press operator until he was drafted into the Army in January 1951. He served two years of active duty, 15 months of this time in Ethiopia, and was discharged in January 1953. In February 1953, he entered the University of Kentucky and received his Bachelor of Arts in Social Science Education in 1954. He continued at the University of Kentucky and received a Master of Arts in Geography in 1956.

He was employed by Alabama Polytechnic Institute (Auburn University) as an Instructor of Geography from 1956 to 1959, when he took leave and accepted an assistantship to do graduate work at the University of Illinois at Urbana.

While at Auburn University he began working as a seasonal Park Ranger in Yellowstone National Park during the summer months. He worked a total of ten summers.

In 1961 he accepted a position at Southeastern Louisiana College at Hammond as Assistant Professor of Geography. He held this position until 1968, when he began his full-time doctoral program in forestry at Louisiana State University. He is now a candidate for the Doctor of Philosophy degree in May 1970.

He and his wife Joy have two children, Karen Michelle and John Lewis II.

EXAMINATION AND THESIS REPORT

Candidate: Hershel Clayton Reeves

Major Field: Forestry

Title of Thesis: Effects of prescribed burning on the understory vegetation in pine-hardwood forests of southeastern Louisiana

Approved:

Thomas Hansbrough

Major Professor and Chairman

Max Goodrich

Dean of the Graduate School

EXAMINING COMMITTEE:

Bryant A. Bateman

Paul Y. Burns

Norwin E. Linnartz

Wm. G. McIntire

Date of Examination:

May 6, 1970